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No. I.

1893

THE JOURNAL

OF THE

IRON AND STEEL INSTITUTE

VOL. XLIII.

EDITED BY

BENNETT H. BROUGH

SECRETARY

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NAME.	ADDRESS.	PROPOSERS.
Goodwin, John T. . .	Clydeview, Motherwell, N.B.	John Colville, D. Colville, jun., T. S. Paterson
Hall, Samuel Jervis .	Wainvawr, near Newport, Mon.	E. P. Martin, Isaac Butler, John Green.
Hodgson, James . .	Ulverston, Lancashire	William G. Ainslie, Myles Kennedy, F. S. Ainslie.
Hoyland, George E. .	Clarence Works, Sheffield	Joseph Newton, W. T. Flather, Robert Sykes.
Hurtzig, Arthur Cameron	2 Queen Square Place, London, S.W.	D. Macnee, R. C. Rapier, E. M. Wood.
Jones, David	Dowlais Iron Works, Dowlais	E. P. Martin, Thomas M. Percy, E. H. Saniter.
Krifka, Heinrich . .	Bruckbach - Rosenau, Upper Austria	F. Korb, C. A. Frey, Johann Oser.
Langford, William . .	Limerick Foundry, Great Bridge, Tipton	Sir A. Hickman, A. W. Hickman, Wm. Hutchinson
Laugham, William John	Wood Lane Iron Works, West Bromwich	R. Farley, James Saunders, James Roberts.
Lange, Ernest Frederick Stephen	Windsor Place, Victoria Park, Manchester	John H. Darby, Hy. B. Robertson, Sir Lowthian Bell.
Lewis, David	Gorseinon, Glamorgan	David Richards, James Jones, W. Bright.
Marsh, Arthur . . .	Roway Iron and Steel Works, West Bromwich	Richard Dalgleish, James Saunders, Henry A. Webb.
Porter, John C. . . .	Pittsburgh, Pennsylvania, U.S.A.	A. E. Hunt, George H. Clapp, W. E. Koch.
Robinson, William . .	Headingley, Leeds	W. F. Beardshaw, R. A. Hadfield, S. J. Robinson.
Salomon, Fritz . . .	Essen, Rhenish Prussia	A. Longsdon, A. Thiclen, Edward P. Martin.
Silvester, Harry . . .	Handsworth, Birmingham	John H. Darby, Jas. Roberts, G. K. Harrison.
Smith, Esau Jameson .	North Ormesby, Middlesbrough	Franklin Hilton, D. Evans, I. Williams.
Smith, John Law . . .	West Hartlepool	Henry Withy, Thomas Mudd, H. Le Neve Foster.
Spaeter, Carl	Coblentz on the Rhine, Germany	G. J. Snelus, A. Thielen, James Riley.
Thompson, James . .	Ettingshall Boiler Wks., Wolverhampton	Sir A. Hickman, A. W. Hickman, Wm. Hutchinson.
Wainwright, John William	Thames View, Erith, Kent	R. Colver, W. F. Beardshaw, Arthur Lee.
Wardlow, Marmaduke	Portobello Steel Works, Sheffield	T. W. Sorby, R. A. Hadfield, William Tozer.
Watts, Edgar	Cumberland Gap, Tennessee, U.S.A.	James Williams, George Wilkinson, C. D. Phillips.
Watts, Edmund Hannay, jun.	Springfield, Newport, Mon.	James Williams, George Wilkinson, C. D. Phillips.
Whitney, George Irwin	Pittsburgh, Pennsylvania, U.S.A.	Sir L. Bell, Sir James Kitson, Sir B. Samuelson.

Sir FREDERICK ABEL then read the following Report of the Council upon the proceedings of the Institute during the year 1892 :—

The following table shows the number of members of the Institute resident in each of the principal iron-making countries of the world other than our own at the end of 1892 :—

**FOREIGN MEMBERS OF THE IRON AND STEEL INSTITUTE,
DECEMBER 31st, 1892.**

In the United States	102
„ France	39
„ Germany	47
„ Belgium	14
„ Spain	15
„ Austria	10
„ Russia	6
„ Sweden	6
„ India	3
„ Canada	3
„ New South Wales	3
Total	248

In addition to the above there are members in China, Singapore, and the United States of Colombia.

DECEASES AND RESIGNATIONS DURING 1892.

An unusually high death-rate appears to have occurred among members of the Institute during the year 1892. The following is a list

Names of Members Deceased during 1892.

J. A. Andrew.	P. M. Parsons.
James Allan.	Maskell W. Peace.
Sir James Brunlees.	G. J. W. Ridehalgh.
Saml. H. Byrne.	Edward Ross.
Benj. Carruthers.	George Ryder.
T. W. Crawhall-Wilson.	C. J. Schofield.
Edwd. F. Crippin.	Wm. P. Shinn.
Wm. L. Darling.	David Simons.
William Firth.	Matthew H. Simpson.
P. W. Flower.	E. Fisher Smith.
Michael H. Grazebrook.	Duke of Sutherland, K.G.
Robt. Horsburgh.	James Taylor.
Richard S. Johnston.	John Varley.
Hermann L. Lange.	Walter Williams.
Wm. Mackinnon.	Henry Woolcock.
Henry Jno. Marten.	John Worton.

Papers Read at the Autumn Meeting.

- On the Manufacture of Iron in its Relations with Agriculture. By Sir LOWTHIAN BELL, Bart., F.R.S.
- On an Apparatus for Autographically Recording the Temperature of Furnaces. By Professor W. C. ROBERTS-AUSTEN, C.B., F.R.S.
- On Alloys of Iron and Chromium. By R. A. HADFIELD, Sheffield.
- On the Liverpool Overhead Railway. By J. H. GREATHEAD, M.I.C.E., London.
- On Failures in the Necks of Chilled Rolls. By CHARLES A. WINDER, M.I.M.E., Sheffield.
- On a New Process for the Elimination of Sulphur. By E. SANITER, Wigan.
- On the Elimination of Sulphur from Iron. By J. E. STEAD, Middlesbrough.
- On the Engineering Laboratories in Liverpool. By Professor H. S. HELE-SHAW, Liverpool.

A new departure was made at the Autumn Meeting of 1892, in so far as receptions and entertainments are concerned. Hitherto it has been the custom for the members of the Institute, and others friendly to it, resident in the places or districts visited, to provide funds for the purpose of affording hospitality to the Institute. These funds have in some cases assumed large proportions, and the Council have for some time past felt that a tax has been thus imposed upon the resources of the localities visited, that was likely to become more serious as the Institute assumed larger proportions, and might, in course of time, interfere with the readiness of desirable districts for meetings to extend invitations for our Autumn gatherings. This view was strengthened by the fact that several other Societies, having much in common with our own, are competitors for the favour of such invitations. The Council therefore decided, last year, to discourage, in so far as in them lay, the raising of local reception funds, and a commencement was made with the new system at the Liverpool Meeting of 1892. They believe that the result demonstrated the wisdom of the course adopted, the Liverpool Meeting having been in all respects successful; no special reception fund was raised for entertainment purposes, but the Institute was treated with much hospitality and courtesy in many directions.

The Council have specially appreciated and recognised the courtesy of the Mayor of Liverpool, in giving an invitation to the Institute to visit Liverpool, in forming a Reception Committee and in otherwise assisting to make the meetings a success. They also desire to refer in grateful terms

the Secretary of that body (at 13 Burling Slip, New York), or with Mr. E. L. Corthell, the Chairman of the Executive Committee (at the Temple, Chicago).

RETIRING MEMBERS OF COUNCIL.

The retiring members of Council are :—

Vice-Presidents.

William Jenkins. Edward P. Martin.
Sir James Ramsden.

Members of Council.

Wm. Beardmore. Benjamin Hingley, M.P.
Andrew Carnegie. Arthur Keen.
R. A. Hadfield.

All of whom are eligible, and offer themselves for re-election. No other names having been submitted, the retiring Members of Council will be continued in office.

THE BESSEMER MEDAL FOR 1893.

The Bessemer medal for 1893 has been awarded to Mr. John Fritz, of the Bethlehem Steel Works, Bethlehem, Pennsylvania, who is well known on both sides of the Atlantic as a metallurgist and engineer of high attainments.

RESIGNATION OF THE SECRETARY.

The members of the Institute will regret to learn that Mr. J. S. Jeans, who has held the post of Secretary for sixteen years, has recently resigned that office. The Council, in accepting his resignation, have recorded their high appreciation of the services which Mr. Jeans has rendered to the Institute, and have given substantial form to their recognition of his faithful devotion to its interests. Opportunity has been taken by the Council of Mr. Jeans' retirement to introduce some modifications in the organisation of the secretarial and editorial arrangements, and Mr. Bennett H. Brough, A.R.S.M., who has for some time past been an assistant-professor at the Royal College of Science, and one of the abstractors of foreign papers for the Journal of the Institute, has been appointed to the conjugate office of Secretary and Editor.

The Honorary Treasurer (Mr. DAVID DALE) read the Annual Statement of Accounts (p. 9).

STATEMENT OF ACCOUNTS FOR THE YEAR ENDING DECEMBER 31, 1892.

INVESTED FUNDS OF THE INSTITUTE.

(Signed) **DAVID DALE, Hon. Treasurer.**

£8572 7 2

- This has since been compulsorily converted into an Annuity up till 1958, with a Sinking Fund to replace the amount of Stock, £1646.

Sir FREDERICK ABEL, having read the report of the Council, moved its adoption.

Mr. T. BARLOW-MASSICKS said he had great pleasure in seconding the adoption of the very able Report just read. It must be a great satisfaction to the members of the Institute to find it increasing year by year as they grew older. He was himself an original member of the Institute, and it was a great satisfaction to him to notice at its head some of the familiar faces that they had known for so many years. Long might they be spared, and long might the Institute flourish.

The motion was unanimously adopted.

Mr. JEREMIAH HEAD moved, "That the most cordial thanks of the members of the Iron and Steel Institute be and are hereby tendered to the President, the Council, and the Honorary Treasurer for their services during the past year." With regard to the President, since the Institute had been founded many years ago, they had had a very large number of able and eminent Presidents, but among them there was none more eminent, and none, he believed, who had fulfilled his duties more faithfully and more to the entire satisfaction of the members than Sir Frederick Abel. Her Majesty the Queen had lately been pleased to confer additional honour on him, and he was sure that the members would agree with him in thinking that they might take a little of the reflected honour upon themselves. Sir Frederick Abel deserved the honour that had been conferred upon him, and they did not forget that when it was conferred he was President of the Institute.

With reference to the members of the Council, the ordinary members, who came to the meetings from time to time and profited by the proceedings, could only know to a very slight extent the labour and the assiduity of the members of the Council, who met much more frequently than the ordinary members did, and made all the arrangements which were so conducive to their enjoyment and instruction. Once a year only the members had the opportunity of letting them know that they were not forgetful of those labours nor ungrateful for them. He

portant Institute. They were all looking forward with great interest and satisfaction to his wise rule. He had been amongst them a constant adviser and a friend to all, and they were perfectly sure that in his hands not only would the Institute not suffer, but it would gain very much. He would now ask the President to be so good as to take the chair and deliver his address.

Mr. E. WINDSOR RICHARDS then delivered the following Presidential address :—

arranged as auxiliaries to the World's Fair. The Council do not propose to make any special provision for the transportation of members to that Exhibition, but have appointed three of their members, Mr. Hadfield, Mr. Snelus, and myself, to be delegates from the Institute to those congresses. Any of our members visiting the Exhibition and taking part in the congresses organised in connection therewith, may rely on a most hearty welcome.

In the Report of the Council reference is made to the resignation of the Secretary and to the appointment of his successor. Mr. Jeans has been Secretary of the Institute for sixteen years—two-thirds of the whole life of the Society. The remarkable progress made during his term of office must be a source of much satisfaction to him on retiring from the position he has so well and so long filled. Mr. Bennett Brough, who succeeds Mr. Jeans, has been known to many of us as an efficient abstractor for the *Journal*. We hope that during his term of office the career of the Institute may be equally prosperous.

It is difficult to decide upon what shall be the drift and scope of a Presidential address.

Sir Lowthian Bell pointed out the desirability of alternate scientific and practical Presidents. I consider myself in the latter category, and, guided by his expression of opinion, I have thought that I would confine my remarks to practical points, and that I might with advantage in this address, as far as time will permit, review some of the developments which have been attained in the metallurgical operations of our iron and steel works. Thus, by recording the various stages of perfection arrived at in those industries in the spring of 1893, a standard of reference, whereby future advances and improvements may be measured, will be in some degree available.

The present meeting is held under circumstances of great depression and gloom for the iron and steel trades. The year 1892 was, in many respects, one of the very worst those industries have ever known. The production of pig iron fell off to the extent of over 600,000 tons. The production of wrought iron and steel was also much under that of some previous years. The most serious falling off, however, was in the production of steel rails. The export of rails in 1892 was not much more than one half of that of

Indeed, were it not for the recent successful calcination of the spathic ores which underlie the Rubio ore, the duration of the district, at the present rate of output of four millions of tons per annum, would have been within measurable distance; but there are very large deposits of spathic ore, the depth and extent of which are as yet unproved. Calcining operations will in the near future be largely carried on, making the spathic ore, which in the raw state contains 43 per cent. of iron and 25 per cent. of carbonic acid, give in the calcined condition 58 per cent. of iron, thus making a very valuable mineral, having only 2 per cent. of moisture as received. Calcining kilns are already erected, one large kiln economically and effectually calcining 1500 tons of raw ore weekly. It seems probable that this successful dealing with the spathic deposit will extend the life of the district fully ten years. It must be understood, however, that this length of life does not apply to the Orconera and Franco-Belge properties.

There are large deposits of ores free from phosphorus in the neighbourhood of Seville and in the south of Spain that will become available, but considerable sums of English money will have to be expended in opening out the mines and conveying the mineral to the ship; but, in the words of Mr. Gill of the Orconera Company, who has seen all the recently discovered large deposits, "there is as yet only one Bilbao."

Under these circumstances, it is natural that our attention should be arrested by the inquiry, whether, if the Spanish supplies were to be suddenly cut off, we could depend wholly on our home mines? The West Coast has raised $2\frac{1}{2}$ millions of tons of ore free from phosphorus, and could most probably increase that quantity to produce $1\frac{1}{2}$ millions of tons of pig iron, should the demand arise.

During the twelve months ending December 1892, the quantity of basic steel made in England was 406,839 tons, of which 108,056 tons was open-hearth steel.

In Germany and Luxemburg, 2,013,484 tons of steel was made from phosphoric ores, of which quantity 186,252 tons was open-hearth, the balance being basic Bessemer steel.

Very much more prejudice has existed in England than on the part of Continental buyers against the use of steel made by

The whole of the pig iron is passed through the refining process. There is no pig iron puddled.

The refinery eliminates the whole of the silicon, and reduces the phosphorus to 0·1 by constant practice with materials of very slight variation, the refiner knowing how to leave the carbon untouched. The puddlers, therefore, have only to perform the duty of eliminating carbon, and the small remaining quantity of phosphorus, in order to obtain a practically pure lump of iron. As it is of vital importance that the puddling should be as nearly perfect as possible, and that the shingling under the steam-hammer be equally well performed, rewards and fines are established in order to procure even quality of workmanship.

The method of inspection of the puddled and hammered lump is as follows:—The foreman every day chooses from each man's work any heat he desires to test, and has one or more pieces broken through. The fractures of these lumps are carefully examined, and numbered according to the degree of perfection attained. These numbers are added up at the week-end, the workmen having the most numbers, representing the worst samples in evenness of quality, have to stand out, or, in other words, are not allowed to work on the following week, whilst the men who have the least numbers, representing the best samples of work during the week, are rewarded by money prizes. This system necessitates the keeping of surplus men, who are waiting to be taken in when others are turned out. The decision of the foreman in judging the samples is never disputed. The samples are exhibited, so that the men have every opportunity of examining for themselves the work they produce, the figures showing each man's work being posted up daily, so that the men are satisfied that no partiality is shown, no errors of judgment made. This system has been strictly carried out day by day, and every day over many years, and creates a very desirable competition, keeping the men's attention concentrated on their work.

The puddler works ten heats of refined metal of 3 cwts. each per turn. The puddled balls are all worked under 50 cwts. steam-hammers into slabs about 12 by 10 inches of varying thickness. Each slab bears the puddler's special mark. These slabs are then piled and repiled to make the required weight for rolling into the various

A range of some dozen 18 tons open - hearth furnaces at Blochairn, all in one line, and having the usual casting-pit in front of each furnace, the ingots and moulds being handled by a steam travelling crane, the men working in a hot, stifling atmosphere, was changed to an arrangement whereby the molten metal is received in a travelling ladle from each furnace, and then conveyed by a locomotive to a central and convenient position, where the operation of teeming the ingots is conducted in comparative comfort. When the ladle of molten metal arrives at its destination, it is lifted off its trunnions by a hydraulic apparatus, and the metal re-poured into a second ladle, mounted on a hydraulic centre casting crane of 20 feet radius, the object of the re-pouring being to obtain a uniform steel by the more thorough combination of the alloys of carbon, manganese, and iron.

The ingot moulds of varying sizes, to hold up to as much as 8 tons of metal, are placed round the circumference of a shallow casting pit in the usual manner, except that the larger end of the ingot mould is uppermost, the object being to give greater density to the smaller end of the ingot, which receives the least amount of work under the steam-hammer or cogging machine, and to put most work on the upper part, which has the greatest need of it.

In order to be able to grasp the ingot for withdrawal from the mould, there are two pieces of iron at the sides of convenient size, easily removable when the ingot is 'sufficiently cooled to be lifted out, which, in the largest ingots, requires about forty minutes.

The ingots, which are usually about 4 feet long, 3 feet 6 inches wide, and 20 inches thick, are then lifted out of the moulds by quick-acting hydraulic cranes, placed in Gjers' soaking-pits, and left there about two and a half hours in order that the heat may have time to equally diffuse itself throughout the mass.

Mr. Riley passes all the ingots produced, nearly 300 tons per shift, through soaking-pits, not finding the least difficulty even with those made in the first cast on a Monday morning, after stopping work on the Saturday. The ingots are then conveyed by simple and effective mechanical arrangements to the cogging-mill, where by successive to and fro passes the ingot is reduced to a slab of a thickness suited to the plates into which it is afterwards to be rolled, and cut up under a very powerful hydraulic shears,

In the rail-mill the average weekly production was 4330 tons—the best was 4674 tons in twelve turns, and the poorest 3865 in eleven turns—the largest tonnage per day was 883 tons, the largest per turn 460 tons of 60-lb. rails.

In the six months ending June 30, 1890, the make was 117,100 tons of ingots and 101,143 tons of rails.

In the autumn of 1890 the two 6-ton converters were changed to a pair of 10-tons, and even then there was not a sufficient supply of ingots to keep the rolling-mill fully at work, but in twelve hours 1774 rails weighing 554 tons were produced in a mill driven by a pair of reversing engines having 48-inch cylinders, and 54-inch stroke, coupled direct to the roll train, and making from 90 to 100 revolutions per minute.

These are results of which any manager may be proud. The American steel-works have so largely increased production, that even that large country is not large enough to supply sufficient occupation for the existing works. But it must not be thought that because I have described an American plant I consider our own country behindhand; quite the contrary, but I fear to describe our capabilities and latent power of production.

All those who manage steelworks, either for the production of rails or ship plates, pride themselves on their power of organisation, not only to increase output, but to maintain high quality.

Then, again, the ingenuity of our engineers has been called into play to substitute mechanical arrangements for the so-called cheap labour. One cannot fail to observe how few men are employed in a mill turning out 5000 tons of finished rails weekly. The heavy ingots are conveyed by small locomotives to the rolling-mills, are moved to and from the several grooves of the rolls by live rollers, are turned over and carried sideways, rails are rolled in 155 feet lengths, are carried to the saws, are cut, are conveyed away, are placed on hot banks to cool, all by ingenious mechanical contrivances. The same may be said of plate-rolling.

It is only when the material becomes cold that labour becomes expensive and troublesome; but the more difficult it becomes the surer will machinery be devised to dispense with it.

So successful have we all been in economically increasing production that we have inundated and swamped the markets for the

SCRANTON STEEL COMPANY.

PRODUCTS OF STEEL WORKS AND RAIL MILL FOR A PERIOD OF THREE MONTHS.

(Average weight per heat, 638 tons.)

Date.	No. of Heats.	Isco's.		RAILS.									
				60 Lbs. (3 Patterns).		60½ Lbs.		94 Lbs.		65 Lbs.		67 Lbs.	
		No.	Weight.	No.	Weight.	No.	Weight.	No.	Weight.	No.	Weight.	No.	Weight.
1890													
Saturday, March 1	27	162	Tons. 185		Tons. Cwt.								
Week ending Mar. 8	805	4,441	5,456	674	180 10								
Do. do. 15	764	4,564	5,230	2,651	710 2								
Do. do. 22	723	3,879	4,908	1,192	319 5			114 10					
Do. do. 29	730	4,320	4,934										
Do. do. Apr. 5	762	4,412	5,179	872	233 11							2,610	780 13
Do. do. 12	696	4,125	4,812	7,561	2,025 7							346	103 9
Do. do. 19	774			10,091	2,702 19							607	181 11
Do. do. 26				2,794	748 7					5,453	1,583 8		
Do. do. May 3												2,002	598 16
Do. do. 10				93	24 18	3,819	1,031						
Do. do. 17				5,814	1,557 6	4,119	1,110					5,214	1,559 11
Do. do. 24													
Do. do. 31													
	9	5,133 6	2	31,743 8,502 5	7,929	2,141		114 10	5,453 1,583 8	10,779	3,224		

6-tons converters were taken out in the autumn of 1890, and 10-tons put in. The results were as follows :—

Weight of Rails.	Number of Bars.	Weight.
70 lbs. per yard.	1730	540·12
70 lbs. per yard.	1774	554·70
75 lbs. per yard.	1687	564·16
76 lbs. per yard.	1624	551·00
76 lbs. per yard.	1708	579·10

Top end first, the ingot goes through the first groove of the b rolls, and is reduced to $11\frac{3}{4}$ inches one way; on the catcher side quickly turned over by a hydraulic manipulator, shifted back with the first groove, and after its second pass through this reduced to a square $11\frac{3}{4}$ by $11\frac{3}{4}$ inches. Shifted sideways manipulator on the roller side, in front of the second groove, makes its third pass and reaches the catcher side reduced to 11. After similar manipulations to the first one, it goes back through second groove, making its fourth pass, and reaches the roller side $9\frac{3}{4}$ by $9\frac{3}{4}$ square. Shifted to the front of the third groove makes the fifth pass, and is reduced to $9\frac{3}{4}$ by $7\frac{5}{8}$ inches. Turned by the manipulator, the bloom has arrived in front of the fourth and last groove, through which it makes its sixth pass, and is down on the feed rollers of the roller side, measuring $7\frac{5}{8}$ by $7\frac{3}{4}$.

Better work than this has been successfully attempted and performed in this part of the mill. With rolls turned purposely, the same ingot was brought down to the same dimensions, also in four passes, but in four passes only. The ingots after the first pass measure $14\frac{1}{2}$ by $10\frac{3}{4}$, after the second pass $10\frac{3}{4}$ by $10\frac{3}{4}$, after the third $10\frac{3}{4}$ by $7\frac{5}{8}$, and after the fourth pass $7\frac{5}{8}$ by $7\frac{3}{4}$, being the same as above. In the fear, however, that such immense reductions were detrimental to the rolls and the engine, this practice was reluctantly abandoned after using it over a year.

The roughing rolls, as already intimated, are coupled directly to the blooming rolls. Their body, in which 4 grooves are turned, is 8 feet long. The manipulator on the roller side brings the bloom in for the first pass in which the forming begins. The bloom is then turned by hand after the first and second pass. On leaving the second pass it moves on to the guillotine shear, where the top or sand is cut off: the piece is then quarter turned once more, and now ready to make its fourth pass through the roughings, arriving at the roller side with a sectional area between 16·78 and 17·90 square inches, properly shaped for flanged rails between 52 and 80 lb.

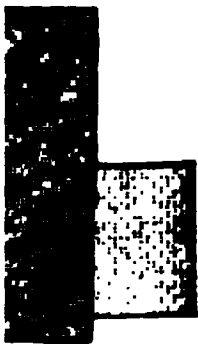
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Rail Ro

SCA



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width across the flange and the height of such rails varying between  $3\frac{1}{2}$  and 5 inches.

The body of the finishing rolls is 63 inches long, and contains 5 grooves, in which all of the above-named sizes are finished. The rolls are coupled directly to a reversing engine 48 by 54, built by Davy Brothers at Sheffield, and moving at a speed of from 90 to 100 revolutions per minute. All the rolls are made of the best obtainable iron. After about 1887 we made our blooming rolls of steel, open hearth castings; the rolls turned according to carefully prepared figures and drawings in the mill itself. No shape, however hard to roll, has ever been missed, nor has a new set of rolls ever been taken out for correction. 32·255 tons of rails have been rolled in one pair of finishings, and 5622 tons have been the best result from one dressing.

All the rolls are stored in a frame building 41 by 101 feet, situated at the northern end of the mill, on iron stands holding two sets each. An overhead hand-power travelling crane of 25,000 lbs. capacity, facilitates the handling of the rolls, and insures quick and safe action.

A small foundry, a small machine shop, a blacksmith's shop, a carpenter shop, and a rumbler house in the yard, some distance away from the mill, all well equipped—and a number of coal shoots beneath overhead trestles, coming in between the foundry and the pattern shop, not yet mentioned, from an adjoining coal mine, complete the plant.

The accompanying diagram (Plate V.) represents the ground-plan of the works.

## VOTE OF THANKS.

Sir JAMES KITSON, Bart., M.P., proposed, "That the best thanks of the Iron and Steel Institute be and are hereby presented to the President, E. Windsor Richards, Esq., for his admirable and instructive address." Having recently experienced the difficulty of finding new subjects and new matter to present to the Institute in the form of a Presidential address, he could sympathise with the new President, and he could also congratulate him on behalf of the members on the very able and remarkable address which he had just presented to them—a practical address which he had almost made poetic by the elegant language in which he had described the details of the manufacture of iron and steel. It was not permissible to criticise the address nor to raise any discussion upon it, and he would therefore content himself with merely moving the resolution, except that he should like to refer for a moment in passing to the paragraph in which the President had called attention to the American volume, in order that he might ask the members to join with him in acknowledging their great indebtedness to the gentlemen who had given so much time to the preparation of that volume and made such interesting reflections upon the visit of the Institute to America. He was not including himself because he had written a short preface to the volume, but in that preface he had ventured to say that the volume would be found to be of great interest, and that it would be a credit to the Institute. He happened to know from personal observation what an immense amount of time and labour Sir Lowthian Bell had given to the preparation of his account of their American proceedings. He had devoted months to the collection of the material which he had placed before the members, and to the preparation of all the particulars which he had set forth in his usual lucid style. It was due to Sir Lowthian Bell that attention should be called to that circumstance, and that thanks should be voted to him for the services which he had rendered. Mr. Snelus also, who had taken charge of the Canadian section, and had given a full account of the proceedings of the representatives in Canada, was entitled to their warmest thanks. The President in his address had spoken somewhat



were connected. It was a happy augury that they had a practical man like Mr. Windsor Richards occupying the chair, and he desired to congratulate him and the Institute on the admirable address which he had delivered.

Mr. HOWARD KENNARD said he rose with great pleasure to second the resolution. The President had delivered one of the most eloquent addresses that had ever been heard in the Institute. There was no man more eminent in the iron trade than their new President. He had first of all been thoroughly educated in South Wales, and then took charge of the largest works in the country, and finally he had retired to the Upper House of the trade, and taken the management of the works that produced the very finest iron not only in this country but in the world. He quite agreed with the President that there was still hope left for the trade, and he also concurred in the remarks he had made as to the shameful way in which the railway system in India was allowed to languish. Notwithstanding the railways there were producing good interest for their money, and there was any amount of money in England ready to be invested in them, there was still a great deal of apathy in the Government, which allowed the country to be practically ruined for want of communication. It was that sort of thing that occasioned depression in the trade. If instead of making the present number of railways in India the Government made ten times the number, they would have some work to give to their men, and should not be deploring the dreadful condition in which the trade was placed. In conclusion, he could only say that they were all proud that the country could produce such men as Mr. Windsor Richards, in whose hands they felt confident that the great industry which they represented would be well cared for.

The vote of thanks to the President was then unanimously agreed to.

The PRESIDENT said he desired to thank the members for the hearty manner in which they had responded to the resolution.



I regret that my professional obligations will prevent my accepting your invitation to be in London, May 24th, to personally receive the medal which bears Sir Henry Bessemer's eminent name, as it would give me an opportunity to more fitly show my appreciation of the honour the Institute has conferred upon me, and to again greet in person the many warm friends whose friendship I prize.

Please convey to all my gratitude and remembrance, and allow me to remain, yours respectfully,  
J. FRITZ.

It was somewhat unfortunate that Mr. Fritz was not present to receive the medal, but Sir Lowthian Bell had kindly promised to receive it for him. Having known Mr. Fritz for many years, and having for him personally such a high regard and respect, it was a very great pleasure to him, as President of the Iron and Steel Institute, to present the Bessemer gold medal unanimously offered for his acceptance. Mr. Fritz began his career as a humble artisan, and by his indomitable perseverance and singleness of purpose he had attained the highest position in his country as a metallurgist, an engineer, and a manufacturer. In 1846 he had charge of the Norriston Ironworks; in 1850 he was mechanical engineer at Safe Harbour; in 1854, as chief engineer and general superintendent, he rebuilt the Cambria Works; and in 1857, in conjunction with his brother, George Fritz, he designed and erected the well-known three-high blooming-mill with automatic feed-tables, also the three-high rolling-mill. In 1860 he designed the entire plant of the blast-furnaces, forge, and mills at Bethlehem, in the capacity of chief engineer and general superintendent. In 1868, in conjunction with Alexander Holley and George Fritz, he erected the Bessemer plant at Bethlehem, which for a period of twenty years held the first place in America for the quality and quantity of its product. He was one of the small band of leaders who so successfully developed the Bessemer process in the United States, and astonished the metallurgical world by the enormous quantities of steel produced from comparatively small installations. During the last few years he, in connection with Lieutenant Jacques, designed, constructed, and managed one of the most important armour-plate, plant, and gun-making works in the world, producing the highest quality of open-hearth steel. The magnitude of this undertaking must be seen to be at all appreciated. On behalf of the Iron and Steel Institute he



## ON THE ELIMINATION OF SULPHUR FROM IRON.

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By J. E. STEAD, MIDDLESBROUGH.

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*PART II.*

## SULPHUR IN THE PUDDLING PROCESS.

SINCE the first part of this paper was read special experiments have been made to ascertain the exact nature of the change which occurs when fluid oxides of iron act upon fluid iron containing sulphur.

The imperfect trial previously described tended to show that provided the cinder is not charged with any large quantity of ferric oxide, no gas having a smell of sulphurous acid is given off; but as this was not conclusive, a more careful and elaborate experiment was conducted, which I think is more satisfactory.

One clay crucible was luted into the upper part of another, so as to produce an air-tight joint.

Into the uppermost crucible was securely fixed a long porcelain tube: the whole arrangement in reality constituting a clay retort, with a porcelain tubulure.

Before the crucibles were cemented together a mixture of coarsely-powdered sulphurous white iron and basic ferrous silicate was placed in the lower one.

The retort with its contents was then placed into a coke furnace, and was so fixed that the porcelain tube projected through the brickwork quite clear of the fire.

To the end of this tube a U tube containing a caustic alkali solution was attached, and when all was thus prepared the furnace was lit. The accompanying sketch (page 49) will make the arrangement clearly understood.

As soon as the melting-point of the iron was attained a brisk



olution of gas commenced, which burnt on applying a light with clear blue flame.

The whole of the gas was passed through the caustic liquor, so that every trace of sulphurous acid which might be given off would be absorbed by it. When the gas ceased to be evolved the furnace was allowed to cool, and the spongy mass of cinder and iron crushed,

and a sufficient quantity of each was separated for analysis, and the caustic liquor, after acidulation and oxidation with bromine water, was examined for sulphuric acid.

The following are the analyses of the several samples, viz. :—

|                                      | Cinder.              |                     |
|--------------------------------------|----------------------|---------------------|
|                                      | Before.<br>Per Cent. | After.<br>Per Cent. |
| Ferrous oxide . . . . .              | 66·87                | 56·25               |
| Ferric oxide . . . . .               | 13·14                | 1·43                |
| Iron combined with sulphur . . . . . | 0·28                 | 3·96                |
| Silica . . . . .                     | 16·70                | 25·26               |
| Sulphur . . . . .                    | 0·16                 | 2·26                |
| Manganous oxide . . . . .            | 0·86                 | 1·86                |
| Phosphoric acid . . . . .            | 0·11                 | 4·34                |
| Not determined . . . . .             | 1·88                 | 4·16                |
|                                      | <hr/> 100·00         | <hr/> 100·00        |

|              |   |   |   |   |   |   |   | Metal.    |           |
|--------------|---|---|---|---|---|---|---|-----------|-----------|
|              |   |   |   |   |   |   |   | Before.   | After.    |
|              |   |   |   |   |   |   |   | Per Cent. | Per Cent. |
| Carbon .     | . | . | . | . | . | . | . | 1·85      | traces    |
| Manganese .  | . | . | . | . | . | . | . | 0·09      | 0·05      |
| Silicon .    | . | . | . | . | . | . | . | 0·05      | none      |
| Sulphur .    | . | . | . | . | . | . | . | 1·83      | 0·586     |
| Phosphorus . | . | . | . | . | . | . | . | 2·10      | 0·901     |

The proportion of metal and cinder used was 200 grammes and 100 grammes ; but it was impossible to determine the proportions remaining after the treatment, as they were so intimately mixed that they could not be separated.

The amount of sulphur absorbed by the caustic alkali was equal to 0·0024 per cent. of the metal treated, or practically only a trace.

It would appear from this that no sulphurous acid is formed directly by the oxidising action of ferrous oxide on the sulphur in fluid iron, but that sulphur existing as sulphide in the iron is found in that state in the cinder.

The next question to answer is whether the sulphur is absorbed directly as such, or whether sulphide of iron is dissolved out of the metal by the oxides of iron.

#### THE ACTION OF FREE SULPHUR ON BASIC FERROUS SILICATE.

An experiment was made in which sulphur vapour was passed through ferrous silicate with the following results:—

|           |   |   |   | Cinder.                          |                          |
|-----------|---|---|---|----------------------------------|--------------------------|
|           |   |   |   | After Treatment<br>with Sulphur. | After Further<br>Action. |
|           |   |   |   | Per Cent.                        | Per Cent.                |
| Sulphur . | . | . | . | 0·21                             | 1·96                     |
|           |   |   |   |                                  | 2·87                     |

It would appear from this that basic silicate of iron is capable of absorbing free sulphur ; but whether it has the power to withdraw sulphur from sulphide of iron in fluid metal (taking the sulphur and leaving the iron) is a question which requires further investigation.

The most probable reaction, to my mind, is that, as basic silicates freely dissolve sulphide of iron, that substance is bodily dissolved



at Hoerde, in which "on the bottom of a glowing basic crucible a mixture of one part of sulphide of iron ground fine and one part of lime was placed, and liquid iron was poured on it immediately."

The iron before and after had the following composition, viz. :—

|                   | Before.<br>Per Cent. | After.<br>Per Cent. |
|-------------------|----------------------|---------------------|
| Sulphur . . . . . | 0·077                | 0·270               |
| Carbon . . . . .  | 0·840                | 0·710               |

"As the powder was only about 5 per cent. of the bulk of the iron, the fact of its absorbing sulphide of iron in spite of the presence of carbon shows its great affinity."

"Here appears the error in the foundation of Saniter's process."

He further states that none of the experiments prove that it is the action of the mixture of lime and calcium chloride which caused the elimination of sulphur, shown by Saniter and myself to take place, and suggests that it may be attributed to some other causes.

He opposes also what he calls a well-known error, that lime is a universal remedy against sulphur, and maintains that "although it is of valuable service in the blast furnace, it is of little use for desulphurising in the converter and reverberatory furnace, on the ground that the relation of lime to sulphide of iron corresponds to that of protoxide of iron, manganese, and others—they dissolve sulphide of iron ;—but that in spite of this power these oxides are not desulphurising agents, and that if we admit that they did, when in basic slag, remove sulphide of iron from liquid iron, there will still remain the lime basic unfavourable slag."

He then describes an experiment in which sulphate of lime was strewn upon the surface of molten iron, contained in a basic-lined vessel, and in which it was shown the iron absorbed 0·416 per cent. of sulphur from the lime sulphate, which experiment practically confirmed that of Finkener.

Based on these experiments, Hilgenstock formulates the following law :—

*"The incomplete desulphurisation in lime basic refining is caused by the regular production of calcium sulphate and its decomposition by the iron bath which re-absorbs the sulphur."*



and lime basic processes is practically this, that in one the slag absorbs the sulphurous gas, and in the other it does not; but it is evidently assumed that sulphurous anhydride is continuously produced in both.

It must be admitted by all that the theories advanced indicate considerable ability and knowledge, and it must also be admitted that the theory that the loss of the oxygen of the compound  $\text{Fe}(\text{CaO})_2\text{S}$ , when heated in hydrogen, is not absolute proof that the compound consists of  $\text{FeO} + \text{CaS} + \text{CaO}$ . On the other hand, Herr Hilgenstock perhaps forgets that in his experiment he did not first frit together his mixture in a closed vessel, but heated the mechanically mixed powders directly in the porcelain tube, and overlooks the possibility of the change  $\text{FeS} + \text{CaO} = \text{FeO} + \text{CaS}$  taking place in the tube although in the presence of hydrogen, yet unassisted by it, and that the compound might not have been affected by the hydrogen till such change had taken place.

His experiment may therefore be said to have been practically the same as mine, but that it is no positive proof that oxide of iron and sulphide of calcium is not the natural condition in which iron, calcium, sulphur, and oxygen associate or arrange themselves when heated together; it is therefore necessary to look in other directions for the proofs which this experiment fails to give.

The statement giving the result of sprinkling sulphate of lime on fluid iron in which the sulphur was absorbed by the iron, on the face of it, seems to assist Mr. Hilgenstock's position; but as we have not been furnished with an analysis of the fluid iron, it is impossible to consider it, knowing as we do that if much silicon was present it would be oxidised, and cause a precipitation of sulphide of iron according to the following approximate reaction—



And as there was no excess of free lime, it does not show or disprove what I have contended, that when free lime in excess is associated with sulphur and iron, in presence of liquid iron or steel, the sulphur is not absorbed by the iron, but is retained in the cinder.



agent, and as the only substance present capable of giving oxygen was the cinder, we are safe in assuming that it most probably was responsible for the oxidation.

This oxidation tends to show either that the mixture consisted of sulphide of calcium and oxide of iron, or as sulphide of iron and lime in an unstable condition, ready to be converted into the calcium sulphide and oxide of iron under the slightest impulse from reducing agents present, carbon and manganese, or that the sulphide of iron is prevented by the excess of lime from returning to the metallic bath in the same way that oxide of iron behaves in the puddling process.

The non-absorption of sulphide of iron from the great mass of the mixture does not support the second hypothesis.

In the next experiment pure carbon metal was melted in one case upon a bed of sulphate of lime after covering with a layer of the same material, and in another the mixture used for the bed and covering consisted of 80 per cent. sulphate and 20 per cent. lime.

The following results were obtained:—

|         | With $\text{CaSO}_4$ alone. |                     | With $\frac{4}{5} \text{CaSO}_4$ and $\frac{1}{5} \text{CaO}$ . |                     |
|---------|-----------------------------|---------------------|-----------------------------------------------------------------|---------------------|
|         | Before.<br>Per Cent.        | After.<br>Per Cent. | Before.<br>Per Cent.                                            | After.<br>Per Cent. |
| Carbon  | 3·950                       | 1·40                | 3·95                                                            | 2·3                 |
| Sulphur | 0·008                       | 0·075               | 0·008                                                           | 0·008               |

The fusions were made in lime-lined crucibles.

Here the results tend to show that sulphate of lime, when not associated with free lime, does give a portion of its sulphur to liquid iron, but that an excess of free base prevents it.

In the experiment with Cleveland iron a notable amount of phosphorus was removed. In order to ascertain what the effect of  $\text{Fe}(\text{CaO})_2\text{S}$  is upon phosphide of iron containing no other elements than phosphorus and iron, they were melted together in a lime-lined crucible and the resulting metal and slag were carefully examined, with the following result:—





condition before the steel was poured, and the experiment was conducted on a larger scale than in previous trials.

The following results were obtained:—

| Description.        | Before.   | After.    |
|---------------------|-----------|-----------|
|                     | Per Cent. | Per Cent. |
| Carbon . . . . .    | 0·380     | 0·400     |
| Manganese . . . . . | 0·403     | 0·186     |
| Silicon . . . . .   | 0·112     | 0·028     |
| Sulphur . . . . .   | 0·184     | 0·121     |

In all these trials with  $\text{Fe}(\text{CaO})_2\text{S}$  there is direct evidence of the presence of an oxidising agent, but in none any evidence of the presence of free sulphide of iron.

The latter experiments were not so satisfactory as could be wished, but they are quite sufficient to prove that the material in the crucibles had acted upon the steel, for both the manganese and silicon are shown to have been removed.

We have now apparently most conflicting evidence. Mr. Hilgenstock's own experiments in my hands give exactly opposite results to those obtained by him.

In carefully reading the description of how the trial was made at Hoerde, and comparing it with my own, we notice this slight difference. At Hoerde the mixture of sulphide of iron and lime was not previously fritted by heating (which it was in my trials), but was placed as a mechanical mixture into the crucible the moment before the steel was poured on the top of it.

Now it appears to me that in this experiment the sulphide of iron and lime must have been in a separate state at the time the steel was poured upon them, consequently the sulphide of iron being free would be partially absorbed by the steel and partly by the lime.

In other words, there were two bodies at the moment the steel and mixture were brought together ready to absorb sulphide of iron, and according to the results the lime, as we should naturally expect, got the most, for of the 0·70 per cent. of sulphur in the 5 per cent. of mixture used, the lime retained 0·507 per cent., and the steel 0·193 per cent.

Had the mixture previous to pouring the steel upon it been



whilst the silicates rose to the surface or the carbon oxides passed off as gas.

Now, taking into consideration the knowledge we now have, there can be little doubt that the oxide of iron at first produced near the tuyeres does dissolve a portion of the sulphur from the bath, and possibly the higher oxides of iron may react on this sulphide and form sulphurous acid; but judging from the fact that there is practically no loss of sulphur in the early stages of the blow, we may safely assume that it is reduced again by the iron, and never allowed to reach the lime slag.

It seems to be forgotten that the basic Bessemer process is very similar to the acid process, and that practically in neither is any sulphur removed up to the time when the carbon is burnt out.

In one process there is no basic lime slag, and in the other it is present.

If sulphurous acid was formed, and reached the siliceous slag incapable of retaining it, it would most surely escape as sulphurous acid, and the metal would contain less sulphur; but it does not contain less, and as the changes in the acid and basic Bessemer processes are practically the same during the first stages, I cannot see how sulphurous acid can ever reach the lime slag, or how sulphate of lime can be formed.

From what I have shown it is clear that metallic oxides in the puddling process do not oxidise sulphur to  $\text{SO}_2$  directly, but that  $\text{SO}_2$  is without doubt formed at a secondary stage by the action of the higher oxides of iron (always present) upon the sulphide in the cinder.

It has been practically proved that sulphate of lime in the lime added to the charge in the converter causes an increase of sulphur in the metal, but I have not been able to obtain any account showing what proportion of it is so absorbed.

I can understand how a portion of it during the early stages of the blow would get into the metal, for the silica formed very rapidly produces a siliceous slag with the lime, and this might cause a precipitation of sulphide of iron.

This leads at once to the consideration of the behaviour of sulphur in the basic Bessemer process.

SULPHUR IN THE BASIC BESSEMER PROCESS.

Most carefully taken samples have been placed at my disposal by Mr. Jos. Walton, who obtained them from the Glengarnock Steel Works.

These samples were taken at various periods during the progress of the blow in the Bessemer converter.

They were all examined in my laboratory, with the following results :—

Analyses of Metal.

| Description.   | Metal.    | 1st Period.    | 2nd Period.   | 3rd Period.     | 4th Period. |
|----------------|-----------|----------------|---------------|-----------------|-------------|
|                |           | Desiliconised. | Decarburised. | Dephosphorised. | Steel.      |
|                | Per Cent. | Per Cent.      | Per Cent.     | Per Cent.       | Per Cent.   |
| Carbon . . .   | 2·32      | 2·180          | 0·07          | 0·02            | ...         |
| Manganese . .  | 0·66      | 0·200          | 0·09          | 0·06            | ...         |
| Silicon . . .  | 1·57      | 0·300          | 0·07          | trace           | ...         |
| Sulphur . . .  | 0·16      | 0·148          | 0·16          | 0·08            | 0·070       |
| Phosphorus . . | 1·85      | 1·920          | 1·53          | 0·04            | ...         |

Corresponding Cinder.

| Description.           | 1st Period.    | 2nd Period.   | 3rd Period.     | 4th Period. |
|------------------------|----------------|---------------|-----------------|-------------|
|                        | Desiliconised. | Decarburised. | Dephosphorised. | Steel.      |
|                        | Per Cent.      | Per Cent.     | Per Cent.       | Per Cent.   |
| Lime . . . . .         | 44·30          | 47·00         | 46·70           | ...         |
| Magnesia . . . .       | 0·72           | 0·86          | 1·80            | ...         |
| Manganous oxide . .    | 6·60           | 4·46          | 2·51            | 10·79       |
| Ferrous oxide . . .    | 4·38           | 8·23          | 14·02           | 9·00        |
| Ferric oxide . . . .   | 1·29           | 1·00          | 4·29            | 2·14        |
| Alumina . . . . .      | 0·35           | 0·26          | 0·30            | ...         |
| Silica . . . . .       | 39·20          | 29·80         | 14·90           | ...         |
| Phosphoric anhydride . | 2·61           | 7·83          | 14·86           | ...         |
| Sulphur . . . . .      | 0·16           | 0·10          | 0·36            | 0·36        |
| Phosphorus . . . .     | 1·14           | 3·41          | 6·49            | ...         |

|                                                                       |                |                 |                    |
|-----------------------------------------------------------------------|----------------|-----------------|--------------------|
| Probable per cent. of liquid slag on 100 per cent. of metal . . . . . | Per Cent.<br>7 | Per Cent.<br>11 | Per Cent.<br>27·00 |
|-----------------------------------------------------------------------|----------------|-----------------|--------------------|

Sulphur in lime used = 0·054 per cent.

Assuming that the weight of slag per cent. of metal used was

as given, we have the following sulphur account up to the end of the after-blow :—

| <i>Sulphur in Cinder.</i>                                                  |   | Sulphur.<br>Per Cent. |
|----------------------------------------------------------------------------|---|-----------------------|
| 27 per cent. of cinder at 0·36 per cent. sulphur                           | . | 0·097                 |
| Less sulphur added in the lime, 15·2 per cent., at 0·054 per cent. sulphur | } | 0·008                 |
| Total received from metal                                                  |   | 0·089                 |

| <i>Sulphur removed from Metal.</i>                      |   | Sulphur.<br>Per Cent. |
|---------------------------------------------------------|---|-----------------------|
| 100 parts of raw iron contained                         | . | 0·160                 |
| Less 85 parts of blown metal at 0·080 per cent. sulphur | . | 0·068                 |
| Total removed                                           |   | 0·092                 |

The sulphur removed during the fore-blow calculated from the analyses of the cinders is as follows :—

| <i>After 1st Period.</i>                                                                                  |                       |
|-----------------------------------------------------------------------------------------------------------|-----------------------|
| The sulphur in 7 per cent. slag at 0·16 per cent. sulphur, less 0·025 carried in by the lime, is equal to | 0·009 on 100 of metal |

| <i>After 2nd Period.</i>                                                                                   |                        |
|------------------------------------------------------------------------------------------------------------|------------------------|
| The sulphur in 11 per cent. slag at 0·10 per cent. sulphur, less 0·026 carried in by the lime, is equal to | 0·008 on 100 of metal. |

Mr. C. H. Ridsdale, of the North-Eastern Steel Works, has kindly provided me with the results of his experience, which are as follows :—

| Description.                                      | Sulphur   | In Slag.  |
|---------------------------------------------------|-----------|-----------|
|                                                   | Per Cent. | Per Cent. |
| 1. Metal poured into vessel                       | 0·100     | ...       |
| 2. After blowing five minutes                     | 0·118     | ...       |
| 3. At the drop of flame                           | 0·118     | ...       |
| 4. At first sampling                              | 0·074     | 0·377     |
| 5. At finish of blow before adding ferromanganese | 0·071     | 0·391     |
| 6. Steel taken fifteen minutes after No. 5        | 0·057     | 0·480     |



|            |   |   |   |   |   | Phosphide. |           |
|------------|---|---|---|---|---|------------|-----------|
|            |   |   |   |   |   | Before.    | After.    |
|            |   |   |   |   |   | Per Cent.  | Per Cent. |
| Iron       | . | . | . | . | . | 87.50      | 86.20     |
| Phosphorus | . | . | . | . | . | 12.38      | 10.10     |
| Manganese  | . | . | . | . | . | 0.12       | 3.24      |

|                 |   |   |   |   |   | Oxide.    |           |
|-----------------|---|---|---|---|---|-----------|-----------|
|                 |   |   |   |   |   | Before.   | After.    |
|                 |   |   |   |   |   | Per Cent. | Per Cent. |
| Phosphoric acid | . | . | . | . | . | 0.05      | 11.2      |

It is clear from these results, that under certain conditions phosphorus is capable of reducing, and does reduce, oxide of manganese. It probably does so in the basic converter when an excess of lime is present in the slag. It is a little more difficult to prove that the manganese so reduced effects an elimination of sulphur. It would appear that whether the manganese is present in large or small quantity in the slag, desulphurisation is effected about equally in each case.

Dr. Wedding may, however, have in his possession the practical proofs which I have failed to obtain, and if that is so, we should all welcome a communication from him to this Institute giving us the benefit of his knowledge.

After the experiment previously described, which clearly demonstrated that fluid oxides of iron remove sulphur from iron without the formation of sulphurous anhydride, the changes during the after-blow appear to be simple enough, for it is necessary only to remember that the conditions at the final stage of the Bessemer process approximate almost exactly to those which exist in the first stage of the puddling process. It must be remembered, too, that the oxide of iron present in excess in both processes most probably behaves in the same way in each, dissolving out from the metal the sulphide, which, in passing upwards through the metal in the basic Bessemer process, is finally received by the calcareous slag, where, I contend, it is converted into sulphide of calcium and oxide of iron, but where, according to Hilgenstock, it must remain as sulphide of iron.

The fact that, when the sulphur has been received into the basic slag, there is no tendency for it to return to the bath, which it never does, is most conclusive proof that either no sulphide of





In the results given herein such elimination amounted to 0·010 per cent. and 0·014 per cent.

This has generally been attributed wholly to the manganese, but it seems most probable that the calcareous slag itself may have had some effect in removing it.

I have not had an opportunity of investigating this point, but I hope before long to make the necessary trials.

SULPHUR IN THE ACID BESSEMER PROCESS.

Three charges of metal, and the steel produced from them, have been examined, with the following results :—

|       |   |   |   |   |   |   | Sulphur.  |           |
|-------|---|---|---|---|---|---|-----------|-----------|
|       |   |   |   |   |   |   | Before.   | After.    |
|       |   |   |   |   |   |   | Per Cent. | Per Cent. |
| No. 1 | . | . | . | . | . | . | 0·057     | 0·057     |
| No. 2 | . | . | . | . | . | . | 0·066     | 0·047     |
| No. 3 | . | . | . | . | . | . | 0·044     | 0·055     |

The results here seem to be variable, and cannot well be explained without further trials.

The average of the three results is as follows :—

|                |   |   |   |   |   |   | Per Cent. |
|----------------|---|---|---|---|---|---|-----------|
| Sulphur before | . | . | . | . | . | . | 0·054     |
| Sulphur after  | . | . | . | . | . | . | 0·053     |

This is equivalent to about 10 per cent. elimination of sulphur from the original metal, 100 parts of which would give about 90 of steel.

SULPHUR IN THE ACID AND BASIC OPEN-HEARTH PROCESSES.

No opportunity has been afforded for the more careful study of the behaviour of sulphur in these processes.

I must therefore reserve this for future investigation.

THE HILGENSTOCK OR HOERDE PROCESS.

Since our last meeting metal mixers have been introduced into two works in this country, with, I have been informed, most satisfactory results. It is hoped that in the discussion detailed

information will be given of the working of this process by those who have had it under their control.

SANITER PROCESS.

The following results were obtained since the last meeting in my presence at the works of the Wigan Iron and Coal Company.

*Crude Metal Process.*—On three separate occasions metal from the blast-furnace was purified.

The material used and the metal before and after treatment were carefully treated in my laboratory, with the following results:—

| Description.              | Mixtures Placed on the Ladle Bottom. |         |         |                     |        |
|---------------------------|--------------------------------------|---------|---------|---------------------|--------|
|                           | 1.                                   | 2.      | 3.      | 4.                  | 5.     |
| Lime . . . . .            | ...                                  | 200     | ...     | ...                 | 114    |
| Carbonate of lime . . .   | 350                                  | ...     | 350     | 350                 | 114    |
| Chloride of calcium . .   | 180                                  | 180     | 180     | 180                 | 71     |
| Fluor-spar . . . . .      | ...                                  | ...     | ...     | ...                 | 71     |
| Weight of metal treated . | 10 tons                              | 10 tons | 10 tons | 7 tons<br>16 cwt.s. | 9 tons |

| Number. | Crude Metal. |           |            | Refined Metal. |           |            |
|---------|--------------|-----------|------------|----------------|-----------|------------|
|         | Silicon.     | Sulphur.  | Manganese. | Silicon.       | Sulphur.  | Manganese. |
|         | Per Cent.    | Per Cent. | Per Cent.  | Per Cent.      | Per Cent. | Per Cent.  |
| 1.      | 0·148        | 0·671     | 0·173      | 0·055          | 0·355     | 0·145      |
| 2.      | 0·345        | 0·578     | 0·288      | 0·224          | 0·387     | 0·259      |
| 3.      | 0·521        | 0·145     | 1·296      | 0·373          | 0·050     | 1·181      |
| 4.      | 0·345        | 0·166     | 1·294      | 0·073          | 0·036     | 1·096      |
| 5.      | 2·290        | 0·118     | ...        | 2·170          | 0·038     | ...        |

| Number. | Sulphur Removed. |           | Sulphur in Slag. |
|---------|------------------|-----------|------------------|
|         | Per Cent.        | Per Cent. | Per Cent.        |
| 1.      | 0·316            | 47·0      | 5·67             |
| 2.      | 0·191            | 33·4      | 5·49             |
| 3.      | 0·095            | 65·0      | 3·57             |
| 4.      | 0·130            | 84·0      | 3·50             |
| 5.      | 0·080            | 67·8      | 1·88             |

*Analyses of Slags.*

| Description.                                                               | No. 3.    | No. 4.    |
|----------------------------------------------------------------------------|-----------|-----------|
|                                                                            | Per Cent. | Per Cent. |
| Chlorine . . . . .                                                         | 14.60     | 14.90     |
| Calcium . . . . .                                                          | 8.20      | 8.40      |
| Calcium . . . . .                                                          | 4.46      | 4.37      |
| Sulphur . . . . .                                                          | 3.57      | 3.50      |
| Lime . . . . .                                                             | 35.32     | 35.89     |
| Magnesia . . . . .                                                         | 0.57      | 1.08      |
| Ferrous oxide . . . . .                                                    | 1.00      | 0.39      |
| Manganous oxide . . . . .                                                  | 4.18      | 2.52      |
| Alumina . . . . .                                                          | 3.70      | 2.67      |
| Silica . . . . .                                                           | 24.60     | 25.90     |
| Phosphoric anhydride . . . . .                                             | 0.07      | 0.07      |
|                                                                            | 99.77     | 99.69     |
| Iron . . . . .                                                             | 0.77      | 0.30      |
| Manganese . . . . .                                                        | 3.22      | 2.00      |
| Sulphur . . . . .                                                          | 3.57      | 3.50      |
| Sulphur capable of being combined with the<br>manganese and iron . . . . . | 2.21      | 1.34      |

In purifying phosphoric iron containing very little silicon, phosphorus is oxidised, and is removed and retained by the slag as phosphoric acid.

Thus in No. 1 trial the slag contained 3.21 per cent. of phosphoric anhydride, and the crude iron only 0.14 per cent. of silicon.

This confirms my own laboratory experiments, and goes far to prove that sulphide of iron is dissolved by the chloride of calcium and lime from the crude iron, and is converted into sulphide of calcium and oxide of iron, and that the oxide so formed then reacts on some of the phosphorus, producing phosphoric anhydride, which in presence of lime basic slag forms phosphate, the oxide at the same time being reduced to iron, which returns to the bath.

It must not, however, be forgotten that any moisture in the chloride of calcium or any carbonic acid associated with the lime will also produce oxide of iron, and that these will also act as oxidising agents.

The fact that the iron and manganese are not in nearly sufficient quantity in the slag from Nos. 3 and 4 to combine with the sulphur present is absolute demonstration that sulphide of calcium must be present.

The reactions in this process are exceedingly complex, and there



Samples of the metal and scrap used, and of those taken from bath, had the following composition:—

| Description.         | Pig Iron. | Scrap.    | Mixture.  | 4.5.      | 5.15.     | 7.15.     | 9.15.     | 11.30.    | 12.30.    |
|----------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
|                      | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Carbon . . . . .     | 2.560     | 0.150     | 2.030     | 0.410     | 0.380     | 0.180     | 0.150     | 0.120     | 0.180     |
| Sulphur . . . . .    | 0.400     | 0.050     | 0.310     | 0.294     | 0.247     | 0.175     | 0.160     | 0.099     | 0.052     |
| Phosphorus . . . . . | 3.260     | 0.070     | 2.460     | 1.380     | 0.170     | 0.120     | 0.080     | 0.060     | 0.070     |
| Silicon . . . . .    | 0.672     | 0.010     | 0.500     | 0.028     | 0.019     | 0.019     | 0.020     | 0.028     | 0.056     |
| Manganese . . . . .  | 0.374     | 0.560     | 0.420     | 0.210     | 0.06      | 0.10      | 0.120     | ...       | 0.670     |

The accompanying diagram (Plate VI.) will make the changes which occur plain.

#### ON THE IRREGULAR DISTRIBUTION OF SULPHUR IN IRON AND STEEL.

On this point an analyst cannot but speak feelingly, for there can be little doubt that different results, obtained by different chemists, which have been most discordant, have been attributed in many cases to the inefficiency of the analyst, when in reality the true cause has been due to difference in the drillings taken from various parts of the piece of iron or steel.

It is a well-known fact that just as in freezing ingots of peaty water the impurity is in great measure concentrated in the central axis of the mass, or, in other words, in that part which is last to become solid, so steel and iron, in passing to the solid state during crystallisation, tend to throw to the centre the impurities; consequently in certain central parts of the solid steel and iron there is frequently found a segregation consisting of material containing a very much larger proportion of carbon, sulphur, and phosphorus than the average of the whole mass.

It is fortunate that such less pure portions are not thrown to the exterior, but are concentrated in that part of the mass where they are least likely to have an injurious effect when the iron or steel containing such segregation is subjected to mechanical strains or stress.

It has been my experience that, as a rule, the larger the mass, and the more elevated the temperature at which steel is cast, the greater will the segregation be.

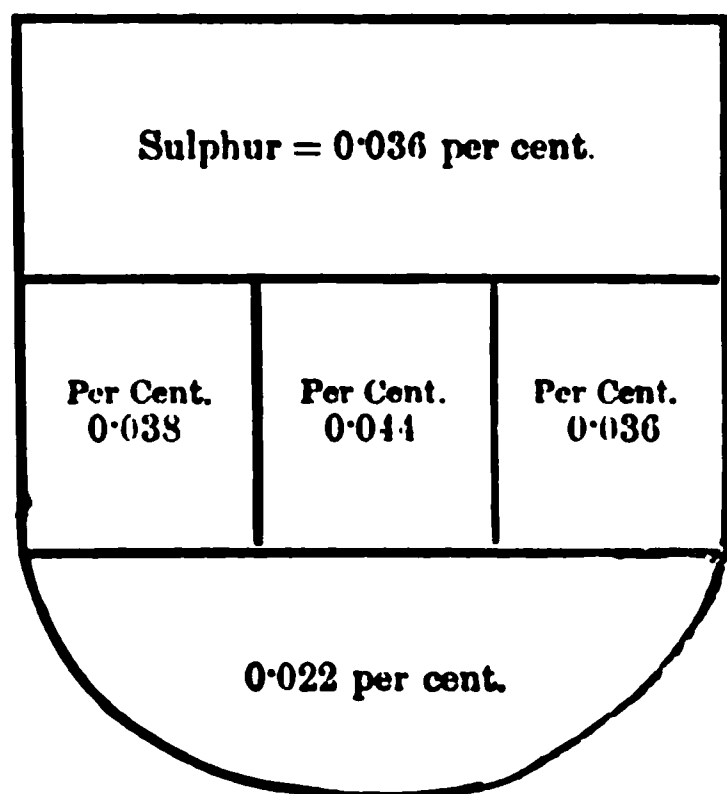


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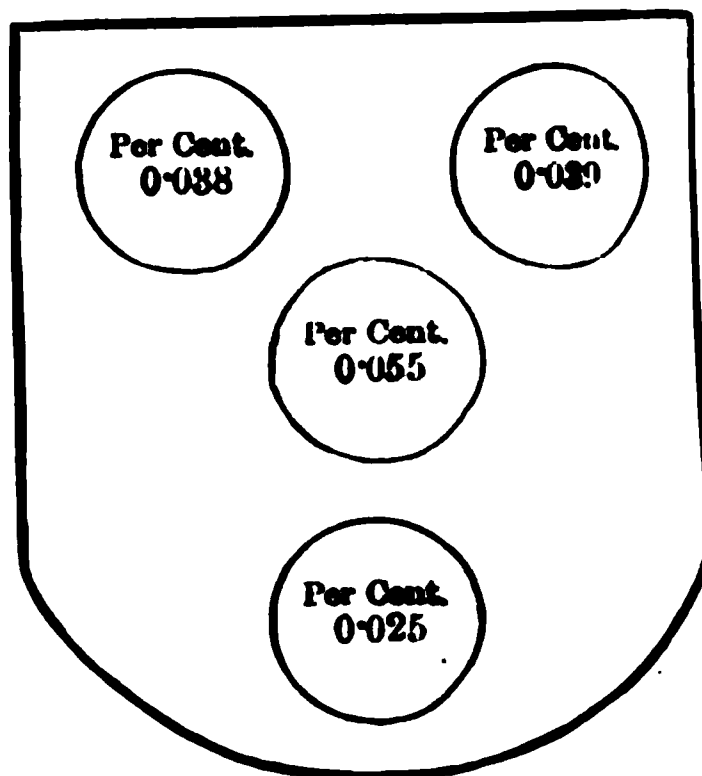
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*Hematite Pig Planed.*

Average of mixed planings from  
the whole section.  
Sulphur = 0.038 per cent.

*Hematite Pig Drilled.*

Average of drillings mixed together  
in equal proportions.  
Sulphur = 0.039 per cent.

In this pig iron there is very clear evidence of segregation in the centre of the pig, for there is about 45 per cent. more sulphur in that part than in the average of the whole pig.

If drillings be taken from a pig at the points marked on the right of the diagram, and be mixed together in equal proportion, a fair average will be obtained.

In concluding this second communication, considering that the only object of my investigation has been to obtain truth, I hope that what I have written will result in a valuable discussion, so that more light will be thrown upon a somewhat complex subject, and that theoretical errors due to myself or to others may no longer be allowed to remain to hamper future progress and to pose as scientific truths.



| Number.     | Sulphur Before.<br>Per Cent. | Sulphur After.<br>Per Cent. |
|-------------|------------------------------|-----------------------------|
| 1. . . . .  | 0·248                        | 0·074                       |
| 2. . . . .  | 0·150                        | 0·064                       |
| 3. . . . .  | 0·148                        | 0·067                       |
| 4. . . . .  | 0·095                        | 0·052                       |
| 5. . . . .  | 0·134                        | 0·059                       |
| 6. . . . .  | 0·100                        | 0·043                       |
| 7. . . . .  | 0·168                        | 0·057                       |
| 8. . . . .  | 0·094                        | 0·048                       |
| 9. . . . .  | 0·158                        | 0·037                       |
| 10. . . . . | 0·124                        | 0·061                       |
| 11. . . . . | 0·146                        | 0·051                       |
| 12. . . . . | 0·108                        | 0·053                       |
| 13. . . . . | 0·190                        | 0·060                       |
| 14. . . . . | 0·258                        | 0·047                       |
| 15. . . . . | 0·082                        | 0·039                       |
| 16. . . . . | 0·097                        | 0·035                       |
| 17. . . . . | 0·072                        | 0·037                       |
| 18. . . . . | 0·076                        | 0·029                       |
| 19. . . . . | 0·092                        | 0·027                       |
| 20. . . . . | 0·098                        | 0·025                       |

The cost of materials is fourpence per ton on these charges, and the other costs, including labour and grinding, have been found to be under twopence per ton.

Among many other results obtained in this way, one may be mentioned which was worked at Dowlais, in which the metal contained only 0·64 per cent. of manganese. The sulphur was reduced from 0·40 to 0·134 per cent. which indicates pretty clearly what may be expected from the ladle treatment under ordinary conditions.

In dealing with larger quantities of metal, where it has been impossible to get the metal quickly enough from the furnace to the ladle, it has been found necessary to make the mixture more infusible. In order to accomplish this, it is desirable to replace a portion of the calcium chloride by the more infusible fluor-spar; in this way the time taken for the fusing of the mixture is considerably lengthened, thus obtaining the desired action on the iron.

Good work also continues to be done at the steel-works, where large quantities of sulphurous iron are also treated in the basic open-hearth, and indeed the record has lately been broken with an iron of the following composition:—

|      |      |      |      |
|------|------|------|------|
| Si.  | S.   | P.   | Mn.  |
| 0·28 | 0·96 | 0·75 | 0·30 |

*Analysis of Bath when Melted.*

|       |       |      |      |
|-------|-------|------|------|
| Si.   | S.    | P.   | Mn.  |
| trace | 0·953 | 0·55 | 0·22 |

*Steel made.*

|      |       |      |       |      |
|------|-------|------|-------|------|
| C.   | Si.   | S.   | P.    | Mn.  |
| 0·12 | trace | 0·07 | 0·026 | 0·47 |

The elimination of sulphur here shown from pig iron to steel is 92 per cent., the steel being of first-rate quality.

The Wigan Coal and Iron Company, at the end of last month, had made over 16,000 tons of basic steel from sulphurous iron, and had treated over 5000 tons of iron in the ladle at the blast-furnace. Besides this, considerable weights have been treated at other works in the country with successful results.

It is interesting, in following up the question of pure iron quality, that is to say, ingot iron from the basic open-hearth furnace, equal in chemical composition and mechanical properties to the best of Swedish bar iron, to give the following analysis of consecutive charges made from white hæmatite pig iron at Wigan:—

| Number. |   |   |   | Carbon.   | Silicon. | Sulphur.  | Phosphorus. | Manganese. |
|---------|---|---|---|-----------|----------|-----------|-------------|------------|
|         |   |   |   | Per Cent. |          | Per Cent. | Per Cent.   | Per Cent.  |
| 1.      | . | . | . | 0·11      | traces   | 0·018     | 0·006       | 0·11       |
| 2.      | . | . | . | 0·085     | "        | 0·016     | 0·009       | 0·16       |
| 3.      | . | . | . | 0·11      | "        | 0·020     | 0·009       | 0·12       |
| 4.      | . | . | . | 0·07      | "        | 0·022     | 0·008       | 0·08       |
| 5.      | . | . | . | 0·115     | "        | 0·016     | 0·008       | 0·11       |
| 6.      | . | . | . | 0·08      | "        | 0·020     | 0·009       | 0·14       |
| 7.      | . | . | . | 0·10      | "        | 0·024     | 0·005       | 0·16       |
| 8.      | . | . | . | 0·14      | "        | 0·014     | 0·004       | 0·21       |
| 9.      | . | . | . | 0·075     | "        | 0·020     | 0·002       | 0·19       |
| 10.     | . | . | . | 0·085     | "        | 0·022     | 0·010       | 0·21       |
| 11.     | . | . | . | 0·145     | "        | 0·018     | 0·007       | 0·25       |
| 12.     | . | . | . | 0·14      | "        | 0·015     | 0·006       | 0·23       |
| 13.     | . | . | . | 0·10      | "        | 0·014     | 0·004       | 0·22       |
| 14.     | . | . | . | 0·17      | "        | 0·014     | 0·008       | 0·27       |
| 15.     | . | . | . | 0·24      | "        | 0·015     | 0·008       | 0·31       |
| 16.     | . | . | . | 0·21      | "        | 0·016     | 0·003       | 0·30       |
| 17.     | . | . | . | 0·15      | "        | 0·012     | 0·002       | 0·30       |
| 18.     | . | . | . | 0·14      | "        | 0·013     | 0·003       | 0·33       |
| 19.     | . | . | . | 0·115     | "        | 0·012     | 0·003       | 0·17       |
| 20.     | . | . | . | 0·14      | "        | 0·017     | 0·003       | 0·23       |
| 21.     | . | . | . | 0·10      | "        | 0·014     | 0·004       | 0·19       |
| 22.     | . | . | . | 0·16      | "        | 0·015     | 0·004       | 0·32       |
| 23.     | . | . | . | 0·105     | "        | 0·014     | 0·010       | 0·19       |
| 24.     | . | . | . | 0·11      | "        | 0·014     | 0·008       | 0·29       |
| 25.     | . | . | . | 0·36      | "        | 0·005     | 0·020       | 0·55       |

This steel has been tested in Sheffield for various purposes for which Swedish bar is used, in making the highest class cutlery and tool steels, with marked success. It has also been found nearly equal to the best charcoal iron for conductivity purposes. It welds splendidly. A piece which had been welded was turned, polished, and pulled in the testing machine; it broke clear of the weld, the line of which it was impossible to detect. The mechanical tests of No. 5, in the preceding table, giving a breaking strain of 24 tons per square inch, with 40 per cent. elongation and 77 per cent. reduction of area, being most extraordinary, and equal to or better than most results of tests given by Swedish bars.

The following table gives the average mechanical test of the steel made in the basic open-hearth from sulphury iron at Wigan:—

| No. | C.       | Si.   | S.        | P.        | Mn.       | Length<br>of Specimen. | Breaking<br>Stress. | Elongation. | Reduction<br>of Area. |
|-----|----------|-------|-----------|-----------|-----------|------------------------|---------------------|-------------|-----------------------|
|     | Per Cent |       | Per Cent. | Per Cent. | Per Cent. | Inches.                | Tons per<br>Sq. In. | Per Cent.   | Per Cent.             |
| 1.  | 0·10     | trace | 0·049     | 0·050     | 0·57      | 8                      | 23·4                | 27·8        | 60·4                  |
| 2.  | 0·115    | „     | 0·053     | 0·059     | 0·60      | 8                      | 24·4                | 30·1        | 52·6                  |
| 3.  | 0·135    | „     | 0·050     | 0·053     | 0·54      | 8                      | 25·1                | 29·6        | 52·7                  |
| 4.  | 0·155    | „     | 0·051     | 0·052     | 0·57      | 8                      | 25·9                | 28·5        | 51·1                  |
| 5.  | 0·205    | „     | 0·041     | 0·049     | 0·56      | 8                      | 27·0                | 27·1        | 47·2                  |
| 6.  | 0·245    | „     | 0·053     | 0·062     | 0·56      | 8                      | 29·2                | 28·2        | 53·6                  |
| 7.  | 0·27     | „     | 0·044     | 0·035     | 0·49      | 8                      | 29·3                | 23·5        | 34·7                  |
| 8.  | 0·315    | „     | 0·062     | 0·070     | 0·70      | 8                      | 33·2                | 23·0        | 31·9                  |
| 9.  | 0·34     | „     | 0·043     | 0·050     | 0·69      | 8                      | 33·4                | 26·2        | 49·0                  |
| 10. | 0·37     | „     | 0·054     | 0·065     | 0·70      | 8                      | 33·1                | 23·3        | 33·8                  |
| 11. | 0·54     | „     | 0·056     | 0·045     | 0·58      | 8                      | 39·1                | 21·8        | 41·8                  |
| 12. | 0·62     | „     | 0·040     | 0·055     | 0·70      | 8                      | 48·8                | 14·0        | 22·8                  |

It is generally conceded by most authorities that about 45 per cent. of sulphur is on an average eliminated in the basic Bessemer blow; this, unfortunately, is insufficient to allow a highly sulphurous iron to be used with advantage in this process. When, however, my process is applied, the conditions aimed at being similar to those required in the basic open-hearth, a very satisfactory elimination takes place; so much so, in fact, that iron containing nearly 0·5 per cent. of sulphur has been made into steel.

In carrying out the process in the basic converter a somewhat larger quantity of lime than usual is put in, together with about 40 lbs. of calcium chloride to the ton of metal. The blowing proceeds in the usual way, no difficulty whatever being experienced.



I had some ingots from the Siemens cast C. 1134 heated on the second day and rolled into 2-inch billets. These were afterwards rolled into  $\frac{1}{2}$  round bars, and tested for tensile strength in my presence. The ingots were 12 inches square, weighing 16 cwt. They were heated (from cold) in 1 hour 20 minutes, and rolled off in twelve passes in the roughing rolls and nine passes in the finishing rolls. I was struck by the remarkably fine quality of the steel. I could not detect the slightest flaw or sign of red-shortness in any of the blooms or in the finished billets, although I examined them minutely. In fact, I never saw any steel roll cleaner or better than this did, and the practical tests fully corroborate the analytical results which follow, and show clearly that this process is most effectual in desulphurising the commonest kind of pig iron, to such an extent that the highest class of steel can be made from it. The materials employed are not costly, and there is no difficulty in carrying out the process and in producing uniformly good results.

The process is adapted either for purifying fluid pig iron direct from the blast-furnace, by running the fluid metal into a ladle having a layer of the purifying materials on the bottom, and afterwards running the metal into pigs or plate metal for subsequent use in the puddling furnace, &c.; or the crude sulphurous pig is treated in the basic open-hearth furnace or Bessemer converter with the patented mixture, as in the casts C. 1134 and C. 1135.

Calcium chloride is the purifying material in admixture with lime. This at present costs 35s. per ton packed in iron drums, f.o.t St. Helens or Widnes. It is made by the United Alkali Co. from residues of the Weldon process, and contains 70 per cent. absolute calcium chloride, 1 to 2 per cent. impurities, the balance being water. It is dried in rough iron dishes in a reverberatory furnace before use.

In purifying the metal in the ladle, fluorspar is sometimes mixed with the calcium chloride to retard the process, and some limestone is used to save lime and produce a boil in the ladle. Fluorspar can also be used with the other ingredients, lime, limestone, and purple ore in the ladle, but the mixture is not quite so efficient as when calcium chloride is used.



The pig iron used in these experiments was made from the following burden :—

|                      |           |
|----------------------|-----------|
|                      | Per Cent. |
| Tap cinder . . . . . | 94·68     |
| Irish ore . . . . .  | 4·21      |
| Purple ore . . . . . | 1·11      |

The analysis of the material showed :—

| Tap Cinder.               |           | Irish Ore.             |           | Silverdale Limestone. |           |
|---------------------------|-----------|------------------------|-----------|-----------------------|-----------|
|                           | Per Cent. |                        | Per Cent. |                       | Per Cent. |
| Iron . . . . .            | 53·8      | Moisture . . . . .     | 14·7      | Calcium carbonate     | 94·0      |
| Manganese . . . . .       | 3·0       | Iron . . . . .         | 21·5      | Magnesia . . . . .    | 0·6       |
| Silica . . . . .          | 16·1      | Silica . . . . .       | 6·3       | Alumina . . . . .     | 0·7       |
| Phosphoric acid . . . . . | 5·5       | Alumina . . . . .      | 30·7      | Iron oxide . . . . .  | 0·5       |
| Sulphur . . . . .         | 0·25      | Titanic acid . . . . . | 2·6       | Silica . . . . .      | 3·2       |
|                           |           |                        |           | Water . . . . .       | 1·0       |

The blast-furnace was running very freely on this mixture ; the slag was fluid, and evidently carried off the bulk of the manganese, from the tap cinder. The colour of the slag at the No. 1 experiment was greenish grey, but the temperature of the blast was lowered for the ladle casts 2 and 3, and the slag was turning black.

DESULPHURISING FLUID PIG IRON IN THE LADLE.

No. 1 Ladle Experiment.

The following mixture, finely ground and dried, was placed at the bottom of a 10-ton ladle lined in the ordinary way. A piece of cast-iron plate was placed on the mixture where the iron struck. The iron was run from the furnace very quickly, the whole 9 tons 1 cwt. being run in three or four minutes ; very considerable boiling took place in the ladle, and dense white fumes escaped from the mixture, but there was no ejection of metal and no trouble. In a few minutes the boil subsided, and the metal was tapped and run into iron plate moulds. It appeared as though considerable heat was developed by the process, for the iron remained perfectly fluid, and there was not the least skull in the ladle.

The mixture employed consisted of—

|                      |           |         |
|----------------------|-----------|---------|
| Dry calcium chloride | . . . . . | 90 lbs. |
| Fluorspar            | . . . . . | 90 „    |
| Limestone            | . . . . . | 225 „   |
| Lime                 | . . . . . | 110 „   |

The metal contained—

|         | Before Treatment. | After Treatment. |
|---------|-------------------|------------------|
|         | Per Cent.         | Per Cent.        |
| Sulphur | . . . . . 0·230   | 0·025            |
| Silicon | . . . . . 0·932   | 0·768            |

The slag contained—

|         | Per Cent.       |
|---------|-----------------|
| Silica  | . . . . . 21·6  |
| Lime    | . . . . . 59·13 |
| Sulphur | . . . . . 2·74  |

Thus there is considerable diminution of silicon and a very remarkable elimination of sulphur, part of which, at least, is found in the slag.

No. 2 Ladle Experiment.

The mixture employed consisted of—

|                      |           |          |
|----------------------|-----------|----------|
| Dry calcium chloride | . . . . . | 180 lbs. |
| Dry lime             | . . . . . | 200 „    |

This was rammed into the bottom of the ladle as before, and the metal run on to it rapidly from the furnace. The boiling was not so violent as in the previous case.

The metal contained—

|         | Before Treatment. | After Treatment. |
|---------|-------------------|------------------|
|         | Per Cent.         | Per Cent.        |
| Sulphur | . . . . . 0·260   | 0·091            |
| Silicon | . . . . . 0·512   | 0·442            |

The slag contained—

|         | Per Cent.      |
|---------|----------------|
| Silica. | . . . . . 23·4 |
| Lime .  | . . . . . 53·0 |
| Sulphur | . . . . . 2·93 |

The pig iron contained rather more sulphur in this case; and the elimination, though not so complete, is very remarkable.  
The weight of metal treated was 9 tons 12 cwt.

No. 3 Ladle Experiment.

Mixture employed.

|            |   |   |   |   |   |   |   |          |
|------------|---|---|---|---|---|---|---|----------|
| Purple ore | . | . | . | . | . | . | . | 120 lbs. |
| Fluorspar  | . | . | . | . | . | . | . | 180 „    |
| Limestone  | . | . | . | . | . | . | . | 225 „    |
| Lime       | . | . | . | . | . | . | . | 110 „    |

Metal.

|         | Before.   | After.    |
|---------|-----------|-----------|
|         | Per Cent. | Per Cent. |
| Sulphur | .302      | .096      |
| Silicon | .745      | .495      |

Slag.

|         | Per Cent. |
|---------|-----------|
| Silica  | 20.60     |
| Lime    | 53.00     |
| Sulphur | 3.91      |

is case also the elimination of sulphur is very considerable, ing to nearly 65 per cent. of the original quantity. Weight l, 9 tons 14 cwt.

Experiment in the Basic Open-Hearth Furnace.

pig iron employed was the same as in the previous experi- run into pigs in the ordinary way. The scrap was a mixture inds. Calcium chloride was the purifying reagent. ollowing are particulars of this charge:—

C. 1134.

- 12 tons white cinder pig iron.  
3 tons steel scrap.  
1 ton 10 cwt. limestone  
15 cwt. purple ore  
1 ton 7 cwt. 2 qrs. lime  
1 ton limestone  
16 cwt. 1 qr. pottery mine  
7 cwt. of 70 per cent. calcium chloride
- Charged with the metal.

Used for feeding.
- 15 cwt. of No. 3 common pig (1.5 per cent. P), used for pigging.  
1 cwt. 1 qr. 20 lbs. of 80 per cent. ferro-manganese added in steel ladle.  
Ingots made, 14 tons 15 cwt.  
Furnace full, 11.25 A.M.  
Furnace tapped, 10.35 P.M.

metal had all been melted down some time when No. 1 (melted sample) was drawn at 5 P.M.  
—i. F

At 5.20, about 2 cwt. of dry calcium chloride was charged, then more lime, then further 2½ cwt. of calcium chloride.

At 6.10, No. 2 samples of metal and slag were drawn. More limestone and about 12 cwt. of pottery mine were then charged.

At 7.15, No. 3 sample drawn.

At 8.15, No. 4 sample drawn, and about 4 cwt. phosphoric No. 3 pig iron added.

At 8.20, more lime added, then further 2½ cwt. calcium chloride.

At 8.30, 4 cwt. No. 3 pig added. Sample tested for sulphur.

At 9.10, No. 5 sample drawn.

At 9.15, more pig charged. Both samples tested for sulphur.

At 10, sample tested for sulphur.

At 10.35, No. 6 sample drawn and furnace cast.

The followed tabulated statement shows the composition of the metal and slag at the various stages :—

| Description.    | Scrap.    | Pig Iron. | Melted Sample No. 1. | Melted Sample No. 2. | Melted Sample No. 3. | Melted Sample No. 4. | Melted Sample No. 5. | Melted Sample No. 6. | Final Steel. |
|-----------------|-----------|-----------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|--------------|
|                 | Per Cent. | Per Cent. | Per Cent.            | Per Cent.            | Per Cent.            | Per Cent.            | Per Cent.            | Per Cent.            | Per Cent.    |
| Combined carbon | ...       | 1.270     | 0.200                | 0.090                | 0.07                 | 0.060                | 0.060                | 0.055                | 0.100        |
| Silicon . . .   | ...       | 0.186     | 0.060                | ...                  | 0.03                 | 0.006                | trace                | trace                | ...          |
| Sulphur . . .   | 0.06      | 0.379     | 0.320                | 0.181                | 0.14                 | 0.129                | 0.093                | 0.041                | 0.040        |
| Phosphorus . .  | ...       | 2.568     | 1.075                | ...                  | 0.591                | 0.163                | 0.054                | 0.027                | 0.030        |
| Manganese . .   | ...       | ...       | 0.200                | ...                  | ...                  | ...                  | ...                  | ...                  | 0.504        |
| Time . . . . .  | ...       | ...       | P.M.<br>5            | P.M.<br>6.10         | P.M.<br>7.15         | P.M.<br>8.15         | P.M.<br>9.10         | P.M.<br>10.35        | ...          |

Corresponding Slags.

| Description.           | 1.        | 2.        | 3.        | 4.        | 5.        | 6.        |
|------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                        | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Silica . . . . .       | 18.30     | 15.00     | 14.20     | 12.80     | 11.60     | 10.80     |
| Ferrous oxide . .      | 5.39      | 3.59      | 3.79      | 4.11      | 5.65      | 7.19      |
| Ferric oxide . . .     | 3.50      | 2.60      | 2.60      | 2.60      | 2.80      | 2.60      |
| Lime . . . . .         | 49.24     | 49.60     | 50.00     | 50.94     | 55.64     | 57.00     |
| Sulphur . . . . .      | 0.315     | 0.576     | 0.507     | 0.480     | 0.659     | 0.645     |
| Phosphoric anhydride . | 11.75     | 16.10     | 19.20     | 22.49     | 18.74     | ...       |
| Alumina . . . . .      | ...       | 6.00      | ...       | 4.00      | ...       | ...       |
| Calcium chloride . .   | ...       | 5.87      | ...       | ...       | ...       | 3.09      |



The proceedings were resumed on THURSDAY, MAY 25—Mr. E. WINDSOR RICHARDS, President, again occupying the chair.

The PRESIDENT said that, in discussing the two very interesting papers on desulphurisation, it was desirable to bear in mind that there were two difficulties to contend with. The first was having to use an iron for steel-making high in silicon and low in sulphur. The high proportion of silicon caused great wear and tear of the converter linings or furnace bottoms, and there was also a great waste of metal. The second difficulty was caused by an iron low in silicon and high in sulphur, which removed the first difficulty. But they were met by another, namely, the steel being hot-short, required some process of desulphurisation. He asked, therefore, whether that second trouble, with the extra cost of desulphurising, was not as great as, if not greater than, the first? Was the Saniter process so absolutely trustworthy that it could be left in the hands of ordinary workmen in constant every-day practice? Was there not an intermediate course to pursue, so as to avoid the two difficulties and the complication of a third process? They knew that many thousands of tons of good steel had been made from pig iron not too high in silicon and not too high in sulphur. Was not that intermediate course the best of the three to pursue?

Having known Mr. Stead a great number of years, and having great faith in his work, he would refer for a moment to that part of Mr. Stead's paper which described the Saniter process (p. 67). He would take No. 1, in which the mixture was composed of 350 lbs. of carbonate of lime, and 180 lbs. of chloride of calcium. In the analysis of the crude metal given it would be found that there was 0·148 per cent. of silicon, while sulphur was as high as 0·671, and from those two analyses they would, of course, expect a very small quantity of manganese—0·173. The analyses of the refined metal gave 0·355 per cent. of sulphur, showing an elimination of 47 per cent. only. That was a metal absolutely useless for steel-making. He had asked before, and he would ask again, Why make such a pig iron? Take No. 3, which seemed to be a fairly good pig iron. The silicon was 0·521, the sulphur 0·145, the manganese 1·29 per cent.; the sulphur









He was using that language not merely as a matter of chemical interest, but as one which might tend, and he had no doubt would tend, to throw very great light on the conduct which they must pursue hereafter. But at present, before they went very deeply into the argument as to whether the thing was chemically possible or not, he would like to have it clearly demonstrated that the results claimed for that particular process could be maintained in actual practice.

Mr. J. P. WALTON said he thought that they were deeply indebted to Mr. Stead for his very important papers on the "Elimination of Sulphur from Iron and Steel." These papers constituted an exhaustive résumé of the state of their knowledge of the matter at the present moment, and enriched as they were by so many laboratory experiments undertaken to get at the right understanding of the reactions which took place in the practical working of the industry with which they were all connected, made their communication to the Institute a fact on which they might well congratulate themselves. He had a few remarks to make on one or two of the points dealt with which might possibly tend to remove a little of the obscurity with which they had hitherto been shrouded.

First, the removal of sulphur from iron in the blast furnace. He was entirely at one with Mr. Stead in the facts detailed in the first paper. Those facts could not have been stated more clearly or more concisely. Turning to the statements made in Part I. on the effect of manganese in the blast furnace, after an interesting account of the views which had at different times been expressed as to the reason why manganese should remove sulphur, Mr. Stead finally gave his own view of the matter in the following words:—"From the above considerations, we may safely grant that the effect of manganese in a blast furnace in removing sulphur depends on a portion of the manganese at first reduced entering the metal, where it combines with the sulphur, and leaving the metal again, carries it off to the slag as sulphide of manganese." He (Mr. Walton) was not prepared to admit that that explanation was sufficiently complete. The action of liquation there dealt with undoubtedly went on in the blast furnace. At the steelworks of the Glasgow Iron and Steel Company at Wishaw



nace, and then the two actions went on concurrently. He now came to examine the cases recorded by Tucker and Harbord, of a comparatively high manganese content existing along with a high sulphur. Manganese and sulphur only were given; silicon and phosphorus had been omitted. If these had been mentioned the explanation would have been more apparent. The manganese content was high, showing that the furnace which made the iron was working hot. How came it, then, that the sulphur was not low? He would tell them, because he had occasionally succeeded in making a similar pig iron himself. This pig iron was basic, he believed, and was made in Staffordshire. Now basic pig iron in Staffordshire was made from a mixture of mill and tap cinders along with C.B. and manganese ores. Tap cinders contained 15 to 18 per cent. of silica; mill cinder contained 20 to 30 per cent. A good deal of these cinders came mixed in the same waggons, being probably taken from an old heap when cinders were simply thrown away. When that particular quality of pig iron spoken of was made, they had had an excessive quantity of siliceous mill cinder in the burden. Possibly also the fuel and C.B. might have been extra siliceous, and as the other components of the burden—namely, the lime and manganese ore—were unaltered, there was neither lime nor manganese sufficient to cope with the extra silica. In other words, the blast-furnace slag had suddenly become too acid, and consequently the sulphur remained in combination with the iron. He was confident that if the content of silicon and phosphorus were given, they would find that the silicon would be higher and the phosphorus lower than in the ordinary run of iron made.

He now turned to the remarks on sulphur in the basic Bessemer process. Most authorities were agreed that there was a considerable quantity of sulphur removed in the basic Bessemer converter. Still there were exceptions, as was proved by Mr. Stead's own experiments at Eston, and also by Mr. Kupelwieser at Hoerde and at Witkowitz. He (Mr. Walton) thought he was in a position to completely elucidate that point. It was merely a question of the purity of the lime used in the operation. A comparatively small percentage of impurities in the lime made a very considerable difference in its power to remove sulphur (much more than one would think from *a priori* reasoning), and increas-



per cent., lime 95.9 per cent., and just traces of sulphur and phosphorus. It would be seen that it was remarkably pure, and, as he anticipated, the effect was most marked. Cupola-metal samples were not taken, but on the same shift the steel from their ordinary lime was running 0.063 and 0.065 per cent. The moment the pure lime went on, the sulphur was reduced from 0.02 to 0.03 per cent., and as soon as the pure lime was done the steels immediately went up to the old figure. He reduced the quantity used per ton considerably, and yet the sulphur did not exceed 0.03 per cent. He repeated the experiment on two or three occasions with the same results. That, he thought, completed the chain of evidence in favour of his opinion that the removal of sulphur in the basic Bessemer converter was entirely a matter of the purity of the lime used in the operation.

It would be observed, however, that he had dealt with this matter purely from a practical point of view. He would come to the theory presently, but wished to mention at this point that a pure lime like that referred to materially lessened their difficulties with both phosphorus and silicon, and while perhaps not having such a marked influence in the basic open-hearth process, was yet efficacious in carrying away sulphur. Mr. Stead would say that those results did not affect his main position, that when calcium sulphide was once formed, the sulphur was not again given up to the steel. He freely admitted that in the case where he got a large addition of sulphur in the steel, the sulphur was undoubtedly present in the lime as sulphate ( $\text{CaSO}_4$ ). He had been inclined to the opinion that when sulphur existed in the slag, even as sulphide above about 0.4 per cent., it then began to be reduced and to give a portion up to the steel, if that steel was low in sulphur, so that a slag might remove a considerable quantity of sulphur from a pig iron containing, say, from 0.2 to 0.3 per cent. of sulphur, and yet impart a considerable quantity of sulphur if the pig contained only 0.02 to 0.05 per cent. But his views on that matter had been very considerably modified by the papers presented by Mr. Saniter and by Mr. Stead, particularly by Mr. Stead's second communication. Undoubtedly sulphur, under certain conditions, went into the steel, and most likely the action that took place was that explained by Mr. Stead in his second communication. Too much stress, in









These rather irregular results in regard to the sulphur were due, he believed, to a great extent to the vessel, because, as he had said, they had been obliged to use a shallow vessel, and could only try one heat a day; and consequently, though the vessel was warmed up as well as they could warm it with coke, it was pretty nearly cooled when they had to conduct the experiment.

It appeared to him, however, that the Saniter process was well worthy of the consideration of pig iron and steel makers, especially of those who used the metal for puddling. If they could reduce siliceous irons, or the irons which were rather high in silicon for forging—if they could take the silicon out and could make such iron very suitable for forging—then the process was well worthy of their consideration. It had occurred to him that in using a mottled iron the sulphur had always been a trouble with the puddlers, but if they could use the Saniter process and remove the sulphur, then they could have an iron low in silicon, which was very suitable for puddling. The reason which led them to make those crude experiments was that in the Cleveland district they were using as much ore from Spain as they were native ironstone from the mines only six or seven miles off, and if they could introduce a process which would enable them to use more of the native stone and so employ considerably more men, that would be a great benefit to the district.

Mr. F. W. HARBORD said that he considered that desulphurisation was merely a result of a fluid basic slag. The calcium chloride really acted as Mr. Walton had mentioned, and enabled a lot of lime to be dissolved in the slag and to be brought into intimate contact with the metal. He remembered that in dephosphorising at various times he had repeatedly noticed that if they could get a fluid slag rich in lime early, the dephosphorisation was much more rapid in the basic open-hearth furnace. By putting chloride of calcium into an open-hearth furnace, that would enable them to carry a heavier lime burden on the slag without its becoming infusible. This, he thought, was borne out somewhat by the experiments given by Mr. Stead with the Saniter process—in No. 5, for instance, where he used fluorspar and less than half the usual amount of chloride of lime. The



moistened, it was decomposed and sulphuretted hydrogen was given off in vast quantities. The slag, too, became disintegrated in a way that showed that there was a compound that was most easily split up. That being the case, it would seem that the most reasonable vehicle to use to remove sulphur from iron in the processes of steel making would be calcium, but the difficulty was how to get calcium so as to act upon the sulphur during those processes.

He thought, therefore, that great credit was due to Mr. Saniter for having arrived at what he thought would turn out to be an exceedingly valuable plan. There was no question that Mr. Saniter's experiments were now beyond the initial stage. They were now practical operations, and Mr. Saniter had given quite sufficient examples to show that the practical results were certainly to be relied on, when they were carried out in a proper and skilled manner.

Mr. Stead had, he thought, entirely controverted the opinion of the German metallurgists, that oxide of iron was the vehicle which carried out the sulphur, and that the sulphur remained, combined as sulphide of iron. He thought there could be no question that whether it was that those highly basic slags had the power of holding in solution and effectually sealing up the sulphide of iron, or whether it was—given sulphide of iron and calcium in such a condition that an interchange could take place—that that interchange did take place, the fact remained that the sulphur did go into the slag, and that it remained there and was not acted upon by the iron. The balance of all the evidence that Mr Stead had brought forward clearly proved that there was a reaction taking place between the sulphide of iron and the calcium compound, resulting in the formation of sulphide of calcium and in the decomposition of the sulphide of iron, and that that was due largely to the fact that those fusible basic slags, while they were fluid, had the power of holding sulphide of calcium in solution in such a way that no change could take place by the action of the iron. He thought there could be no question, judging from a very careful study of the experiments that had been made, and from the results obtained, that it was possible to remove the sulphur and to transfer it to the slag, and that once it was in the slag it was not again taken up by the iron.













efficiency of the process in eliminating sulphur. The experimental stage had long been passed. At Wigan something like 18,000 tons of steel had now been made in the open-hearth furnace from pig iron containing sulphur from 0·10 to 0·35 per cent. Of course it might be asked why pig iron so high in sulphur should be made; but the difficulty was now that, with the mixture used, they could not make pig iron low in sulphur without the aid of manganiferous ore, and that they found that in taking off the manganiferous ore they were put to a very great disadvantage in making the pig iron which they formerly made: hence they had now adopted the Saniter process. The steel made from it had been sent out to different parts of the country for engineering work generally, for wire, and for forgings, and he had no hesitation in saying that their analyses and the mechanical tests of the steel made would bear comparison with those of any other steel made from pure pig iron. With regard to the remarks made by Mr. Martin, he went down to Dowlais with Mr. Saniter, and could say that every facility was offered them there to experiment with metal direct from the blast-furnace. No doubt they had some irregular results. He was not quite prepared to say why those results were irregular, but he thought that with a little more practice those difficulties could be overcome. He was sorry that Mr. Saniter was not present, as he would have been better able to discuss the matter than himself, but unfortunately that gentleman was ill. At Wigan they had looked upon this process as a decided success, both in the open-hearth and when taking the metal direct from the furnace. They had treated in the blast-furnace between 6000 and 7000 tons of direct metal. They had sent it out into the market as basic pig iron; it had been treated either in the open-hearth furnace or by the Bessemer basic converter, and it had given every satisfaction; therefore he thought they had a right to assume that at Wigan, at any rate, the Saniter process had met with success. The process would be very useful in Staffordshire, where tap-cinder abounded. It would render available a pig iron of a very cheap character, and render it possible, as Mr. Saniter had stated, to produce steel of the very highest quality from very inferior metal. He did not know that he could add very much to what had been so ably stated by Mr. Snelus. When Mr. Snelus was at the



Mr. STEAD, in reply to the discussion, said that some of the speakers had pointed out that the objection to the Saniter process was the irregularity in the results. Now one of the most astounding things about the process was that in the trials described it had been possible to get out 60 per cent. of sulphur in such a crude way. What were the possibilities of the process if they applied it in a mechanical way? They would undoubtedly be very much better than they were now. A very wide-bottomed ladle, with a thin layer of powdery material on the bottom, was not the best condition in which, theoretically or mechanically, to get intimate mixture between two substances. Supposing that trials were made to find the effect of oxide of iron upon fluid iron by putting the oxide in the ladle in the same way, how much phosphorus would they get out? About 1 per cent. perhaps of the total, and it would be a very irregular result, and every experiment would vary. But because they could only get a very small proportion of the phosphorus out, would they say that oxide of iron was no good? They knew that oxide of iron did remove phosphorus. Only bring the conditions together which favoured the thorough intermixture of the oxide with the fluid iron, and they would get a very perfect elimination of phosphorus. Mr. Snelus had pointed out, and he fully confirmed him in that, that if the metal boiled very thoroughly with the mixture in the ladle, there was a more perfect elimination of sulphur than when it was very quiet. That led them up to one cause of irregularity in the process, which was that the metal, if it was very cold from the blast-furnace—that was, if it was low in manganese, low in silicon, and low in carbon—was rather sluggish. It had not got the life in it that hotter metal had, and consequently it did not boil well, and there was not that intermixture made which always occurred with hotter material. That was one of the causes of irregularity. If mechanical or other means could be used to effect intermixture when the metal was sluggish, the sulphur would in all probability leave the metal. He was afraid that some of his friends had imagined that in making the remark that the Saniter process was “likely to be useful” he was therefore condemning the other process in the mixer. That was not the case. He had never done anything of the kind. There was plenty of room for both processes, and he was quite certain, just as he had been six months



Mr. STEAD said that if sulphurous acid was given off in those large quantities, the slag must have been pretty considerably saturated with silica, which had probably been derived from the limestone or from the ladle. The question Professor Huntington asked was a very important one indeed, whether the chloride of calcium was harmful to vegetation? The quantity actually left in the basic slag at the termination of the basic process was exceedingly small, and, without making any investigation whatever, he should have been inclined to believe that such a minute quantity was immaterial. But for all that, they could not accept anything without proving it. Theory was all very well in its place, but they wanted solid fact. In order to ascertain whether the chloride of calcium was injurious, he tried to get information from other sources, but he had not been able to ascertain from any written authority whether the chloride of calcium was really very injurious or not in a small quantity. He therefore watered a portion of the lawn in front of his house with a 2 per cent. solution of chloride of calcium for about a week during the recent dry weather. He also watered another strip, alongside of the first strip, with water containing no chloride of calcium. The experiment had only continued for a week, but he had not seen the slightest difference in the growth of the two strips of grass. A 2 per cent. solution of chloride of calcium would be a very much stronger solution than would come from a very small quantity of basic slag distributed over the land. The next experiment he tried was a little more severe. He soaked a lot of garden peas in chloride of calcium solution of strengths varying from about 1 per cent. up to 5 per cent. He thought that if chloride of calcium was very injurious to germination, the absorption by the peas of such a large quantity as 5 per cent. would perfectly prevent germination. As a matter of fact, the peas that were soaked in water alone, and the peas that were soaked in a 5 per cent. solution of chloride of calcium, and those that were soaked in a 2 per cent. solution, and in a 1 per cent. solution, all germinated and sprouted in the same way. The same seeds after germination were planted in soil and were watered with a 2 per cent. solution of chloride of calcium, and were compared with seeds treated with water alone. The difference was very marked, for the growth of the former was



ladle treatment was not successful in reducing it to the required limit, this iron was desulphurised to a further extent in the basic open-hearth, and made into very good steel. The President then referred to No. 3 of Mr. Stead's figures, and pointed out that very good steel could be made with about 0·07 per cent. of sulphur from this iron, without the preliminary desulphurisation. That percentage of sulphur would not meet the specifications of many engineers, but, had the desulphurised metal been used in the converter, the steel, by the same reasoning, would have contained only 0·035 per cent. of sulphur. He would also call the President's attention to examples 1 and 14 in his paper, where the sulphur was reduced from a quarter per cent. to 0·07 and 0·04 respectively. After converting into steel the metal should have contained only 0·035 and 0·02 per cent. of sulphur, but, had the iron treated been used direct in the converter, worthless steel containing 0·12 per cent. of sulphur would have been made.

In reply to Sir Lowthian Bell, he would point out that the results obtained on a few grains of iron in crucibles, set forth in his first paper, had been fully borne out in practical experience on masses of twelve tons of molten iron. The Wigan plant mentioned by Mr. Snelus had already, at the time of the meeting, been working for five months, thousands of tons of iron having been treated. The twenty consecutive results given showed a regular and efficient removal of sulphur. The process was carried out, as stated by Mr. Snelus, by ordinary workmen using an ordinary amount of care.

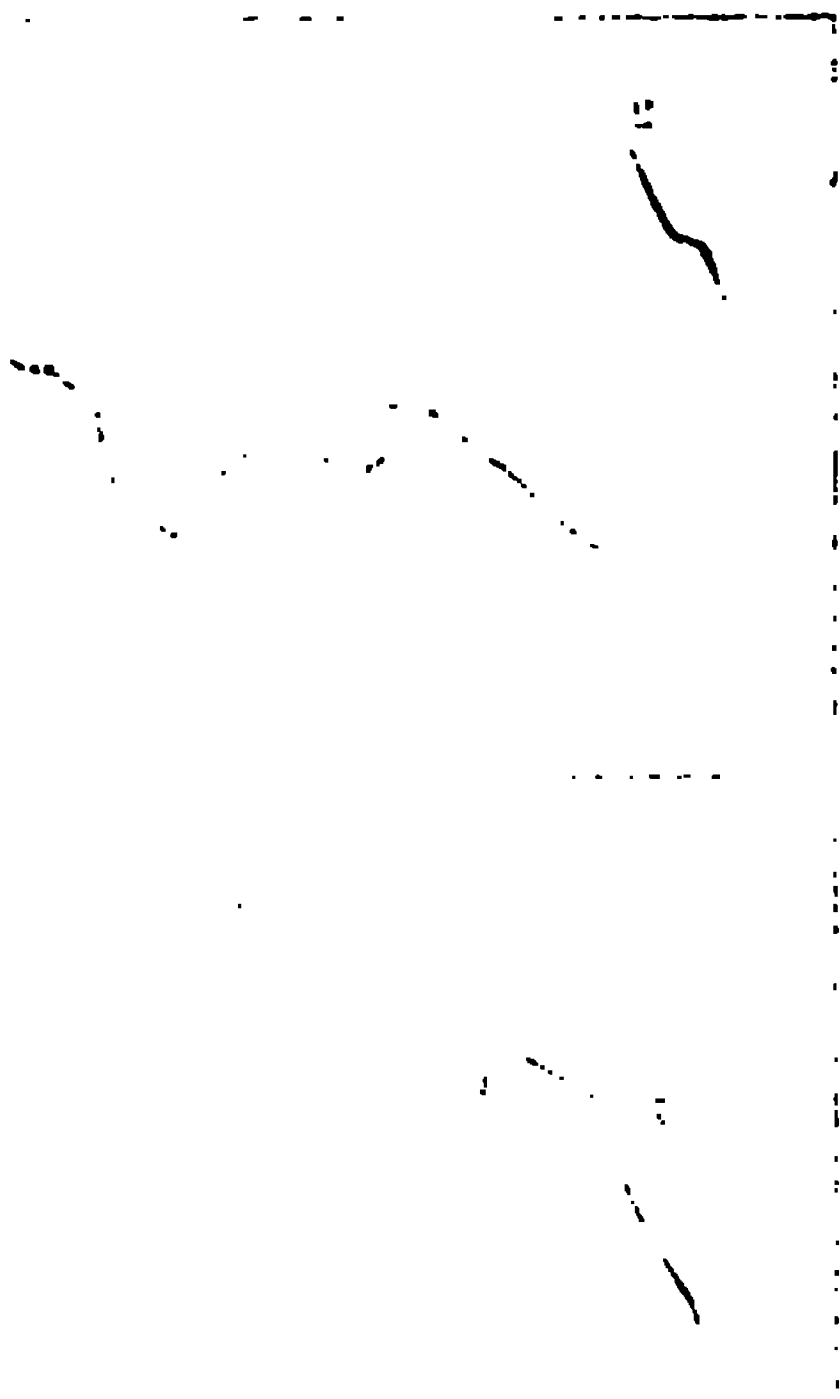
A few words of explanation were necessary as to the irregular results mentioned by Mr. Martin in the Dowlais trials. These trials were made on hæmatite iron in the molten metal ladle, which was then conveyed to the steel-works and the metal blown in the acid-lined converter. The sulphurous slag, which was in most cases poured into the converter along with the metal, was the cause of the irregularity. Sometimes the sulphur returned from the slag to the steel, at others it did not, the reason for which was difficult to explain. He had no hesitation in saying that charge after charge could be successfully desulphurised in the ladle, but it was absolutely necessary to separate the slag from the metal before attempting to use the metal for steel.

In the clear and exhaustive remarks of Mr. Snelus there was





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gland, devised by Mr. Charles Bell, and used by him with success in the hot-blast mains at the Clarence Works. The initial difficulties inseparable from a new installation were soon overcome by the energy of one of the author's own students, Mr. R. C. Styles, who received the utmost encouragement and aid from Mr. James, the manager of the Dowlais Cardiff Works.

The anticipation that the "recorder" would prove to be a valuable adjunct of an iron and steel works was amply justified, as the curves obtained by its aid will show. These are now submitted, by Mr. Martin's permission, to the members of this Institute. Plate VII. represents a record for  $23\frac{1}{2}$  hours of the temperature of the hot-blast supplied to a furnace by a series of stoves, numbered respectively Nos. 1, 2, 3. It is a typical record, and, as it represents an excellent example of careful and successful gas-firing, it may be well to describe it in some detail.

It will be seen that the record begins near the top right-hand corner, and shows that the temperature of the blast contributed by No. 2 stove (at 10 A.M. on the 14th of February) had an initial temperature of  $1160^{\circ}$  Fahr. At the end of an hour the temperature of the blast had fallen to  $955^{\circ}$  Fahr., and the gas-man considered that the time had arrived for effecting the connection with a fresh stove, No. 3. As will be seen from the record, this stove contributed blast at an initial temperature of nearly  $1230^{\circ}$  Fahr., and the temperature fell in the course of 1 hour 50 minutes to  $1020^{\circ}$  Fahr., when the blast from No. 1 stove was introduced into the horse-shoe main. Inspection of the curve will show the successive variations of temperature. The record, viewed as a whole, shows that the temperature never rose above  $1400^{\circ}$  Fahr., or fell below  $950^{\circ}$  Fahr. This record shows good, conscientious, careful firing, such as should ordinarily be obtained in works. Complications are, however, introduced by untoward accidents, which, unfortunately, will happen, and diagram No. 2 has been specially selected as indicating the existence of a set of conditions which presented much difficulty.

The record refers to stoves Nos. 4, 5, 6, 7, and begins at 10.30 A.M. on February 25th. For  $2\frac{1}{2}$  hours the temperature of the blast rapidly varied between  $1180^{\circ}$  and  $730^{\circ}$  Fahr., and it is



ing the progress of the record it is frequently possible to diminish the amount of fuel charged into the furnace, and thus to effect economies which may, it is hoped, attain considerable proportions.

If in a given set of conditions 18 units of carbon are required to smelt a ton of iron with the temperature of blast at  $880^{\circ}$  Fahr., 16 units of carbon will still be required if the temperature be  $1660^{\circ}$  Fahr., so that there is clearly a limit to the advantages of heating the blast. A large blast-furnace smelting iron may have a capacity of 35,000 cubic feet, and of this 20,000 cubic feet is in brilliant ignition, and presents the largest mass of fuel in rapid combustion which is employed in any single industrial operation. In view of all the complex problems involved in the working of a blast-furnace, the solution of which depends mainly on thermal conditions, it is truly remarkable that hitherto there has been no sustained effort to accurately measure and record the temperature of the blast, this being the factor of paramount influence, and the one that can be most readily controlled.

The chief advantages which may be claimed for the appliance are as follows:—

1. A check is placed on the gas-men, and, to a less extent, on the men at the furnace top.

2. Inferences may be drawn as to the conditions which prevail in the interior of the furnace.

3. Accurate information may be gathered as to the time of reversal of the valves, and of casual admission of cold blast.

4. Certain indications, afforded by the curves, show that changes have been effected in the accessories of the blast-furnace, such as the removal of tuyeres, alterations in breast-plates, &c., &c.

It should be observed that the appliance is popular with the workpeople, who find that regularity in conducting the details of the various operations means increased output, and, moreover, the gas-men recognise that it is to their advantage to have an autographic record of the way they have done their work.

Since this paper was in type, the author received the following letter from Mr. Martin:—





*DISCUSSION.*

Mr. E. P. MARTIN, on being invited by the President to take part in the discussion, said he had nothing to add to the valuable paper which had been read by Professor Roberts-Austen, except to say that he was very well satisfied with the instrument, that he had ordered another, and that probably that would be followed by a third.

Mr. J. ADAMSON said that after the Liverpool meeting he had communicated with the author to inquire whether the instrument was commercially practicable, and the reply was that at that time it was not; but he (Mr. Adamson) now hoped that it was, because of all things connected with the blast-furnace in modern works, the temperature of the blast seemed the most essential. They had heard from Mr. Martin what they could do at Dowlais with their splendid works, but others could scarcely hope to do the same thing. As far as his experience went (which was very limited), there was more of the second diagram in most iron-works than of the first. He should be very glad to know that it was possible to obtain such an instrument to attach to their plant, and to obtain a continuous record instead of the intermittent one of the Siemens or Hobson pyrometers, as at present used.

Sir LOWTHIAN BELL said that perhaps Professor Roberts-Austen's diagrams gave undue prominence to the inconvenience resulting from variations in the temperature of the blast. No doubt it was much to be desired that the air entering a blast-furnace should be as regular as possible, although it seemed to him that a couple of hundred degrees did not, when continued for a short time, necessarily greatly lower the temperature of the hearth, because the materials came down to the tuyeres impregnated with the heat absorbed from the blast at its normal temperature.

These observations were not made with a view to depreciate the great value of having so admirable an instrument to ascertain



Mr. R. A. HADFIELD desired to bear testimony to the valuable character of the pyrometer described by Professor Roberts-Austen, and to ask him whether he thought it could be usefully applied to annealing purposes, so as to indicate the range of temperature in several furnaces together, and what the cost would be. He wished also to ask Mr. Martin if he had any difficulty with the thermocouple. They had some trouble in this respect with the pyrometer used in their own works. The couples became very brittle after working a certain time. He wished to know whether it would give uniform readings, and whether the instrument as recently improved could be rendered more free from the trouble experienced with vibrations. He had had some difficulty in his works in getting a place where that trouble could be avoided. It was important for steel-founders to have the means of indicating exactly the temperatures of annealing furnaces. Now-a-days steel-founders were expected to get material of very high quality as regards ductility. Instead of 8 or 10 per cent. elongation, they were now asked to supply castings with 15 or 20 per cent., and even higher. It was only by paying special attention to the annealing process that they could obtain these qualities. They were all greatly indebted to Professor Roberts-Austen, who was helping them so much in the accurate study of temperatures—a matter of great importance in dealing with a metal like steel, which was so sensitive to molecular changes.

Mr. SNELUS said he wished to thank Professor Roberts-Austen for the admirable way in which he had perfected his very delicate pyrometer. When the first exhibition of the instrument was made, he very much doubted whether it would be possible to adapt it to the requirements of ironworks. From what he had seen, however, he thought it was perfectly possible, and that it would render very great service to the iron and steel maker. He had paid a good deal of attention to that part of the subject, and confessed his disappointment at never having been able to determine satisfactorily the temperature, particularly the continuous temperature of the hot-blast. There could be no question that it was one of the most important points connected with blast-furnace management; and now that an instrument was available that would from hour to hour and from minute to minute tell its own



the actual variations in the blast. The cost of the appliance was at present about £23.

With regard to the introduction of the apparatus into annealing furnaces, he was glad to say that steps were being taken with that object in view, and two such appliances were now in Sheffield to be applied, he believed, in conjunction with annealing furnaces. He might call Sir Lowthian Bell's attention to the fact that in one particular case (as shown in the diagram) the temperature varied from  $800^{\circ}$  to  $1650^{\circ}$ . That was certainly a very great variation. There was not the slightest doubt that it was to the temperature of the effluent gases they must look for the most important indications as to the working of blast-furnaces. Very high testimony to the efficacy of the appliance was afforded by the following paragraph in the President's address:—"At the Dowlais Company's new works at Cardiff, Mr. Edward P. Martin has attained a production of upwards of 1400 tons per week, using the usual Rubio ore, and with rather less than 20 cwt. of coke per ton." He believed that result was obtained while the autographic recorder was attached to the furnace, and he hoped that its indications had been useful in enabling this output to be attained.

Mr. E. P. MARTIN said that was the case.

The PRESIDENT said he was sure the members would accord a hearty vote of thanks to Professor Roberts-Austen for his interesting paper.

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### CORRESPONDENCE.

Mr. C. LOWTHIAN BELL, referring to the curves he published in the Proceedings of the Cleveland Institution of Engineers, stated that it frequently happened that the remark B.L. (bell lowered) was placed on the diagrams some time before the fall in temperature was apparent. That, of course, was not the case. The temperature *fell* immediately the cold material was put into the furnace, or, in other words, as soon as it passed or was falling through the gases. As soon as the bell was lowered, the



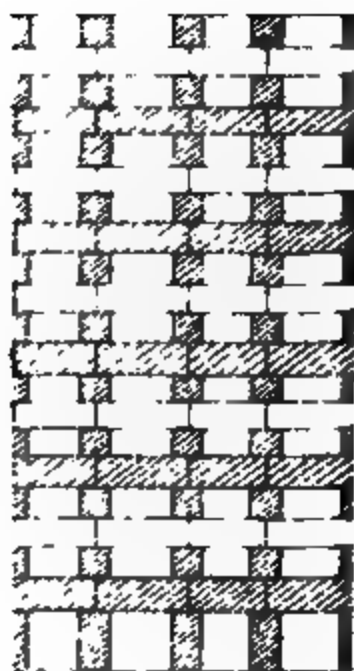
that a clear explanation of the phenomenon was given. directed attention to the circumstance that the escaping gas on their descent lost a portion of their sensible heat, so that the temperature of  $600^{\circ}$  at the top of the furnace might become  $500^{\circ}$  through the effects of radiation from the sides of the down-comer in the passage of the gases down. When the bell was lowered for charging materials, the plenum gas in the throat of the furnace needed to force those gases onward to stoves and boilers ceased, and with the escape into the atmosphere the gases became reversed in the down-comer. They were now pressed upwards by the plenum in the gas main flues below, thus allowing the cooled gases from below to pass the pyrometer placed in their path.

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The following paper was then read:—



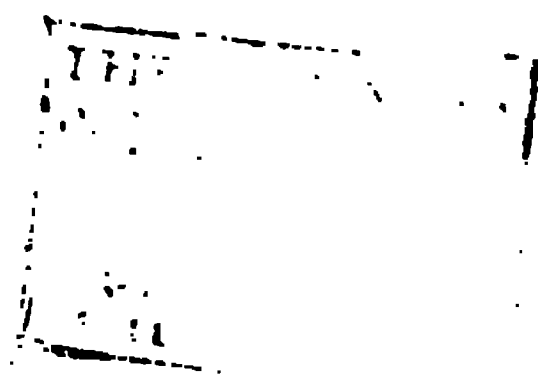
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NOTES ON PUDDLING IRON.

BY JOHN HEAD, F.G.S., M. INST. C.E.

In the year 1868 the late Sir William Siemens read a paper before the British Association on puddling iron, which formed an epoch in the history of the literature of that process. In that paper the theory was advanced that the oxidation of carbon, silicon, and other substances to be removed from pig iron during puddling could be entirely effected by means of oxygen obtained from the fettling used for lining the pan, or by means of that obtained from hammer-scale, or other iron oxide thrown in expressly with the charge.

The theory enunciated by Sir William Siemens was supported by sound argument, and by an experiment made in an open-hearth steel-melting furnace at Birmingham, and has been generally accepted by various authors who have since written on the subject of puddling.

There can be no question that this theory can be realised in practice in a puddling furnace, provided that the pig iron used does not contain an excess of silicon, or that time can be allowed and a low furnace temperature ensured for its elimination. By Table I. which follows, it is seen that the experiment made by Sir William Siemens in the open-hearth regenerative gas furnace, mentioned in his paper referred to, required six hours for its accomplishment. The pig iron was melted and purified upon a sand bed, and under a protecting covering of glass.

TABLE I.

| Description.         | Time.                |                           | C.<br>Per Cent. | SI<br>Per Cent. |
|----------------------|----------------------|---------------------------|-----------------|-----------------|
| Acadian pig iron . . | ...                  | . . .                     | 4.0             | 1.50            |
| Sample No. 1 . .     | After one hour. .    | 0.6 comb.<br>2.3 graph. } | 2.9             | 1.08            |
| Sample No. 2 . .     | After two hours. .   |                           | 2.4             | 0.96            |
| Iron ore added       |                      |                           |                 |                 |
| Sample No. 3 . .     | After three hours. . | . . .                     | 2.4             | 0.76            |
| Iron ore added       |                      |                           |                 |                 |
| Sample No. 4 . .     | After six hours. .   | . . .                     | 0.25            | 0.046           |

Sir William Siemens would have argued, had the question been raised, that molten pig iron on the bed of his open-hearth steel-melting furnace under a protecting covering of glass, was in a very different condition to molten pig iron in a puddling furnace, in intimate contact with iron oxides, and that the elimination of impurities would be much more rapid under these conditions than under those selected for the experiment which he desired to make. That experiment was intended to prove, and did prove, that carbon and silicon can be eliminated from molten pig iron without flame or air coming in contact with the metal under treatment.

Many regenerative gas puddling furnaces were set to work for puddling iron, which were constructed to carry out the process in accordance with this theory; and at some works, notably at those of Messrs. Nettlefolds, of Wellington, Shropshire, these furnaces gave every satisfaction. Messrs. Nettlefolds built about thirty of these puddling furnaces, and continued to use them until they removed their works to Newport, Monmouthshire, when they abandoned the use of iron, and adopted steel as a material for the manufacture of their high-class products. The same kind of furnace was also built at other works; but in some cases it was noticed that difficulties were experienced, which induced Sir William Siemens to make alterations in the flame-ports of his furnace.

The construction of flame-ports shown in the accompanying figure (Plate VIII.) was that adopted by him in 1871 for the puddling furnaces erected at the works of Messrs. Langlois & Co., Basse-Indre (France), and elsewhere. This form of flame-port was not adopted in the first instance, but in consequence of the complaints referred to. It will be seen that in this form a certain amount of contact between the flame and the iron to be puddled is secured; and it is noteworthy that with the adoption of this modification all complaints ceased.

Sir William Siemens would no doubt have observed that this alteration in the flame-ports of his furnace involved a departure from the theory enunciated in his paper read before the British Association a few years previously. When he made that alteration, however, he was fully engaged in perfecting the details of manufacture of the Siemens steel process; he was thus prevented

from following up the puddling process with the energy and thoroughness which he displayed in his early experiments, which experiments, carried out on a scientific basis, under his direction, would undoubtedly have led to most valuable results if they could have been continued. Owing to the circumstance that chemists are not usually employed at ironworks, analyses of the iron puddled, and of the puddled bar produced, were not supplied; but it is thought that the reason alterations were required in the puddling furnaces erected at some works was due to the circumstance that the pig iron treated at those works contained a larger amount of silicon than that at other works.

There are not many analyses of the various brands of pig iron used for puddling, and of the puddled bar produced therefrom, to be found in the numerous metallurgical books and papers which have been consulted; and Tables II., III., IV., and V. contain the only analyses of this kind that have been found.

TABLE II.

Analyses of Puddled Iron, at different Stages of the Operation, made by Messrs. Crace Calvert and Richard Johnson of Manchester (*Phil. Mag.*, September 1857).

| Description.              | Time.    | C.        | Si.       | S.        | P.        |
|---------------------------|----------|-----------|-----------|-----------|-----------|
|                           | O'clock. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Cold blast Staffordshire— |          |           |           |           |           |
| No. 3 grey, charged. .    | 12·00    | 2·275     | 2·720     | 0·301     | 0·645     |
| Sample No. 1 . . .        | 12·40    | 2·726     | 0·915     | ...       | ...       |
| " " 2 . . .               | 1·00     | 2·905     | 0·197     | ...       | ...       |
| " " 3 . . .               | 1·05     | 2·444     | 0·194     | ...       | ...       |
| " " 4 . . .               | 1·20     | 2·305     | 0·182     | ...       | ...       |
| " " 5 . . .               | 1·35     | 1·647     | 0·183     | ...       | ...       |
| " " 6 . . .               | 1·40     | 1·206     | 0·163     | ...       | ...       |
| " " 7 . . .               | 1·45     | 0·963     | 0·163     | ...       | ...       |
| " " 8 . . .               | 1·50     | 0·772     | 0·168     | ...       | ...       |
| Puddled bar " 9 . . .     | ...      | 0·296     | 0·120     | 0·134     | 0·139     |

TABLE III.

The following analyses by Mr. Louis illustrate the changes produced during the puddling by hand of Nova Scotia pig iron (*Ency. Brit.*, Art *Iron*, p. 325) :—

| Description.           |   |   |   | C.        | Si.       | P.        | Mn.       |
|------------------------|---|---|---|-----------|-----------|-----------|-----------|
|                        |   |   |   | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Pig iron in fusion     |   |   |   | 2·36      | 1·11      | 0·36      | 0·78      |
| 8 minutes after fusion |   |   |   | 1·89      | 0·14      | 0·25      | trace     |
| 13                     | " | " | " | 1·75      | ...       | 0·26      | 0·09      |
| 18                     | " | " | " | 1·57      | ...       | 0·23      | trace     |
| 22                     | " | " | " | 1·10      | ...       | 0·23      | trace     |
| 40                     | " | " | " | 0·16      | ...       | 0·09      | 0·07      |

TABLE IV.

Analyses of English iron, made for Sir William Siemens, and published in his paper on “Puddling” of 1868 :—

| Description. |  |  |  | Si.       | S.        | P.        |
|--------------|--|--|--|-----------|-----------|-----------|
|              |  |  |  | Per Cent. | Per Cent. | Per Cent. |
| Pig metal    |  |  |  | 1·97      | 0·08      | 1·160     |
| Puddled bar  |  |  |  | 0·20      | 0·017     | 0·237     |

TABLE V.

In Sir Lowthian Bell’s work on the Manufacture of Iron and Steel, London, 1884, Section “Puddling,” &c., the following analyses of Bowling iron are found :—

| Description.                               |  |  |  | C.        | Si.       | S.        | P.        |
|--------------------------------------------|--|--|--|-----------|-----------|-----------|-----------|
|                                            |  |  |  | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Cold blast pig                             |  |  |  | 3·656     | 1·255     | 0·033     | 0·565     |
| Refined metal                              |  |  |  | 3·342     | 0·130     | 0·025     | 0·490     |
| Malleable iron produced from refined metal |  |  |  | 0·226     | 0·109     | 0·012     | 0·064     |



TABLE VI.

The following analyses of iron have been kindly furnished by the Lilleshall Company :—

| Description.                     | Si.       | S.        | P.        | Mn.       |
|----------------------------------|-----------|-----------|-----------|-----------|
|                                  | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Lilleshall hot blast pig No. 3 . | 1·050     | 0·048     | 0·58      | 1·14      |
| Puddled bar from do. . .         | 0·161     | 0·016     | 0·18      | 0·07      |

TABLE VII.

The following analyses are extracted from a great number of analyses of ironstone, limestone, coal, pig, and finished iron which have been obligingly placed at my disposal by Mr. F. T. Woodcock, who was associated in making these analyses, and sometimes made them entirely himself. They refer to iron made at the Ebbw Vale Company's Cwmbran works in 1858 :—

| Description.              | Si.       | S. and P. | C.        |
|---------------------------|-----------|-----------|-----------|
|                           | Per Cent. | Per Cent. | Per Cent. |
| Pig iron . . . . .        | 1·23      | 0·370     | 2·57      |
| After one hour . . . . .  | 0·41      | ...       | ...       |
| After two hours . . . . . | 0·07      | ...       | ...       |
| Finished bar . . . . .    | 0·05      | 0·023     | 0·315     |

The following analyses of malleable iron alone have been found in the works mentioned against each set.

TABLE VIII.

In Sir Lowthian Bell's work already referred to :—

| Description.                                         | C.        | Si.       | S.        | P.        |
|------------------------------------------------------|-----------|-----------|-----------|-----------|
|                                                      | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Bowling 1½ square bar . . .                          | 0·015     | 0·157     | 0·005     | 0·220     |
| Lowmoor rivet iron . . . .                           | 0·200     | not given | trace     | 0·115     |
| Monkbridge best plate puddled<br>by hand . . . . . } | 0·018     | 0·151     | 0·004     | 0·097     |

TABLE IX.

In Muspratt's Chemistry, p. 435 :—

| Description.             | C.        | Si.       | S.        | P.        |
|--------------------------|-----------|-----------|-----------|-----------|
|                          | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| German strong iron . . . | 0·40      | 0·01      | trace     | ...       |
| Do. weak . . .           | 0·09      | 0·03      | trace     | ...       |
| Welsh puddled iron . . . | 0·41      | 0·08      | trace     | 0·40      |

TABLE X.

In T. Bayley's "Assay and Analysis of Iron and Steel," 1884 :—

| Description.                                          | Combined C. | Si.       | S.        | P.        | Mn.       |
|-------------------------------------------------------|-------------|-----------|-----------|-----------|-----------|
|                                                       | Per Cent.   | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| New British Iron Co.'s }<br>"Lion" brand (ordinary) } | 0·21        | 0·13      | trace     | 0·13      | nil       |

TABLE XI.

In Greenwood's "Iron and Steel," 1884 :—

| Description.                 | C.        | Si.       | S.        | P.        | Mn.       |
|------------------------------|-----------|-----------|-----------|-----------|-----------|
|                              | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| K. B. W. best bar iron . . . | trace     | 0·170     | 0·028     | 0·200     | 0·140     |
| Swedish O O . . .            | 0·075     | 0·114     | 0·032     | 0·004     | trace     |
| Lowmoor armour plate . . .   | 0·016     | 0·122     | 0·104     | 0·106     | 0·280     |
| Round bar W R 3 . . .        | 0·180     | 0·019     | 0·014     | 0·074     | trace     |
| Armour plate . . .           | 0·230     | 0·014     | 0·190     | 0·020     | 0·110     |

TABLE XII.

In Vosmaer's work entitled "The Mechanical and other Properties of Iron and Steel," 1891 :—

| Description.                           | C.        | Si.       | P.        | S.        |
|----------------------------------------|-----------|-----------|-----------|-----------|
|                                        | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Swedish puddled iron . . .             | 0·07      | 0·10      | 0·02      | ...       |
| Yorkshire puddled iron, best . . .     | 0·07      | 0·06      | 0·09      | ...       |
| Yorkshire puddled iron, best . . .     | 0·15      | 0·21      | 0·12      | ...       |
| Staffordshire puddled iron, best . . . | 0·06      | 0·20      | 0·25      | 0·02      |
| Surahamman puddled . . .               | 0·05      | 0·08      | 0·02      | ...       |

Mr. Vosmaer remarks that for puddling, silicon should not exceed 1 per cent. in the pig iron.



modification of the flame-ports of the regenerative gas furnace, so as to obtain some oxidation of the metal by the flame. This is shown by the following analyses of the pig iron used and the puddled bar produced at a works in England, where ordinary iron is being made:—

TABLE XIII.

| Description.                                     | Si.            | S.        |
|--------------------------------------------------|----------------|-----------|
|                                                  | Per Cent.      | Per Cent. |
| Pig iron (average of several analyses) . . . . . | 1·65           | 0·131     |
| Puddled bar, bad . . . . .                       | 0·362          | 0·050     |
| Puddled bar, good . . . . .                      | 0·282<br>0·250 | 0·0315    |

It will be noticed that the chief difference between the bad and the good quality of iron produced consists in the elimination of a little more silicon in the latter case, and the flame-ports of the furnace were altered so as to obtain that result. A different arrangement of flame-ports, however, was adopted to that shown in the figure accompanying this paper, with a view of enabling the oxidising action to be effected either by burnt gases or unburnt air, or again by the admission of cold air upon the surface of the iron in fusion, and particularly to allow the furnace to be worked at will with an oxidising or a reducing flame, great importance being attached to the use of a reducing flame during the balling up of the iron.

The following is an average analysis of Spanish pig iron used for the production of high-quality iron, and analyses of the good and other finished bar iron made therefrom:—

TABLE XIV.

| Description              | Si.       | S.        | P.        |
|--------------------------|-----------|-----------|-----------|
|                          | Per Cent. | Per Cent. | Per Cent. |
| Pig iron . . . . .       | 1·680     | 0·105     | 0·050     |
| Bar iron, bad . . . . .  | 0·327     | 0·033     | trace     |
| Bar iron, good . . . . . | 0·331     | 0·032     | trace     |
|                          | 0·103     |           |           |













them in a small diagram at the meeting of the Institution of Mechanical Engineers held at Birmingham on the 18th of July 1876.\* He might say that those curves entirely confirmed what the speakers in that discussion had already stated, viz., that the bulk of the silicon disappeared in the melting. The sulphur, phosphorus, and manganese went rather quicker at first, but otherwise steadily from beginning to end. The carbon was the one element that held back, and even slightly increased until melting was complete, when it gradually disappeared. The curves produced were really very similar to some curves which the President himself exhibited at an Iron and Steel Institute meeting some years since, in his illustrations of what took place in the basic Bessemer converter. There was no doubt that one thing which made it difficult to determine the constituents of puddled iron was the fact that the impurities are mainly contained in the remnant of cinder mixed with the iron. It was therefore quite clear that the amount of the impurities depended largely on the mechanical processes of shingling and rolling, in removing more or less effectively the cinder from puddled bar or finished iron. Having had considerable and rather unfortunate experience in times past with rotary puddling with the appliance known as the Crampton furnace, he could confirm what Sir Lowthian Bell said as to the very great purity of the wrought iron produced in that way. There was no doubt whatever that it was much purer than was usually got by hand-puddling, and for some reason or other it was much more free from cinder, which might partly account for it. As conducted by that process, however, there was one great difficulty which must permanently have prevented success. It would be remembered that by the Crampton process the furnace was heated by coal-dust. However fine the coal-dust was ground, there was not sufficient time during its passage into and out of the furnace for the solid carbon to be consumed. The gaseous portion of the coal-dust was burnt at once, but a residue of solid coke was left in the form of dust which had not time to get burnt. That fine coke-dust got into the iron, was lapped up in it, and afterwards reappeared in the bar, or the plate, or the rail, or whatever it

\* *Proceedings of the Institution of Mechanical Engineers*, 1876, p. 266, and plates 45 and 46.











the means of oxidation provided in the furnace acted directly upon the substances to be eliminated, or whether, as was maintained by most metallurgists, himself included, there was a double reaction in the puddling furnace, iron being first oxidised, and the oxide of iron thus produced reacting upon the silicon. All he wished to point out was the necessity, when the iron to be puddled contained a large proportion of silicon, of providing in the Siemens regenerative gas puddling furnace means for obtaining a certain amount of oxidation before the metal is entirely fused. This was effected by Sir William Siemens, by the means indicated in the figure attached to his paper, and it was effected by other means in the new-form Siemens furnace, with the object of also ensuring that the balling-up of the metal might be carried out under a reducing flame.

The PRESIDENT said he was sure the members would desire to accord a hearty vote of thanks to Mr. John Head for his paper, which had elicited such an interesting discussion.

### CORRESPONDENCE.

Mr. H. G. GRAVES stated that the author did not appear to have searched very thoroughly the abstracts given at the end of each volume of the Journal of the Iron and Steel Institute, in which the salient features of a large number of papers on puddling were given. Included in these abstracts were complete analyses by Dr. T. Tscheuschner\* of the materials from the ore through the pig iron to the puddled iron, and the piled, welded, and rolled bar. Amongst these the following occurred:—

|                        | Phosphorus. |      |      | Silicon. |      |      |
|------------------------|-------------|------|------|----------|------|------|
|                        | I.          | II.  | III. | I.       | II.  | III. |
| Pig iron . . . . .     | 0·67        | 0·31 | 0·32 | 1·22     | 1·12 | 1·22 |
| Puddled iron . . . . . | 0·15        | 0·12 | 0·12 | 0·25     | 0·28 | 0·20 |
| Rolled iron . . . . .  | 0·06        | 0·08 | 0·09 | 0·24     | 0·28 | 0·18 |

\* 1886, No. I., p. 325.



Numerous analyses were also given by Mr. A. E. Tucker,\* and since 1886 other notes are given by Messrs. Tucker,† Turner,‡ Ranstrom,§ and Jacobsson,|| whilst before that date numerous references to the puddling process would be found in the general indexes.

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The PRESIDENT then announced that the next two papers were "On the Determination of Chromium in Ferro-Chromium," by Mr. William Galbraith, and "On Methods of Determining Chromium, with Notes on the Distribution of Chromium in British Irons," by Mr. J. E. Stead. They would be submitted by title, and if any member desired to make any remarks upon them, and would send them to the Secretary, they would be published in the Journal of the Institute. It was proposed to leave over the last paper on the list, that by Mr. Kupelwieser on "The Manufacture of Basic Steel," until September, as the author was unable to be present, but he had promised to attend the next meeting.

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\* 1887, No. I., p. 412.      † 1888, No. I., p. 323.      ‡ 1891, No. I., p. 119; 1892, No. I., p. 414, and 1892, No. II., p. 519.      § 1891, No. I., p. 376.      || *Ibid.*

## ON THE DETERMINATION OF CHROMIUM IN FERRO-CHROMIUM.

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By WM. GALBRAITH.

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IN Mr. Hadfield's paper on "Chromium Steel" read before this Institute in September last, he rightly, I believe, gives the credit of introducing that metal to Mr. Baur. This was done in England at the works of Messrs. John Brown & Co., Limited, about 1876. At that time there was considerable discussion as to whether there really was chromium present or not, and certainly the determination of 0·05 or 0·10 per cent. chromium in steel by any of the then known methods was not a very simple matter, and moreover was exceedingly tedious. To determine it accurately, I devised, and described in the *Chemical News* early in 1877, a method which served its purpose very well, and enabled the determination to be carried out with great speed and accuracy. As time went on, however, chromium irons were made much richer, and when the Tasmanian iron, with about 8 per cent. of chromium, appeared on the scene, it was thought very rich. To-day, however, chromium irons are made with as much as 60 per cent. chromium, an index of the progress which metallurgy is making. As the metal rose in chromium I found the process was not too satisfactory, and that for two reasons—first, because it became increasingly insoluble in the sulphuric acid; and, secondly, for reasons which I shall presently show.

The process, I may here say, was simply carried out by dissolving the steel or iron in dilute sulphuric acid, to which was then added sufficient potassium permanganate to oxidise all the iron and chromium. This was boiled until all the permanganate was destroyed and the solution filtered, and the chromium determined volumetrically by means of ferrous salts by well-known means. There has been a little difference of opinion as to its utility in the richer chromium irons, and Mr. Hadfield, in the discussion on his



To this was added 5 grammes potassium permanganate, and the solution was again boiled till the permanganate was destroyed (i.e. for about ten minutes). This was filtered and washed, and to the yellow filtrate was added 5 grms. ammonia-ferrous sulphate (containing 13·95 per cent. Fe), and the unoxidised iron was determined with the same bichromate solution. This took 30·3 cc., showing a loss of 10·55 cc., thus—

$$\begin{aligned} 13\cdot95 \times 5 &= 69\cdot75 - 50 = 19\cdot75 \\ 30\cdot30 \text{ cc.} - 19\cdot75 &= 10\cdot55 \text{ cc.} \end{aligned}$$

The experiment was repeated, but this time the chromic acid was not reduced with the sulphurous acid.

The number of cubic centimetres taken were 29·80, showing a loss of 10·05 cc.—

$$29\cdot80 - 19\cdot75 = 10\cdot05 \text{ cc.}$$

Now this shows that the error is not due to non-oxidation of chromium by the permanganate, and in order to ascertain where the loss took place, the following experiments were carried out:—

25 cc. of the bichromate solution, made up to 50 cc., was treated as before, but was not reduced with sulphurous acid.

3 grms. iron salt were taken, which consumed 20·30 cc.—

$$\begin{aligned} 13\cdot95 \times 3 &= 41\cdot85 - 25 = 16\cdot85 \\ 20\cdot30 - 16\cdot85 &= 3\cdot45 \text{ loss.} \end{aligned}$$

The precipitated oxide of manganese (or manganate of manganese) from this was washed off the filter and boiled in water, and again filtered and washed. The filtrate was treated for chromium as above, taking 1 gram. iron salt. The cubic centimetres taken were 11·70 :—

$$\begin{aligned} 13\cdot95 - 11\cdot7 &= 2\cdot25 \\ 3\cdot45 - 2\cdot25 &= 1\cdot20 \text{ loss.} \end{aligned}$$

The washings were never absolutely colourless.

The experiment was again repeated, but this time the bichromate was previously reduced.

With 3 grms. iron salt 20·7 cc. were taken—

$$\begin{aligned} 13\cdot95 \times 3 &= 41\cdot85 - 25 = 16\cdot85 \\ 20\cdot70 - 16\cdot85 &= 3\cdot85 \text{ loss.} \end{aligned}$$

The precipitate, on being treated with water as above, took 11 cc.—

$$13\cdot95 - 11 = 2\cdot95. \quad 3\cdot85 - 2\cdot95 = 0\cdot90 \text{ loss.}$$



only), and that the chromic acid was dissolved easily from the precipitate by its means.

The process thus becomes: Dissolve in sulphuric acid (1 in 6), add permanganate, and boil till precipitate is black; then dilute and make alkaline with caustic soda; filter wash, acidulate filtrate, and treat as before with the ferrous salt and potassium bichromate. As an illustrative test, I took 50 cc. potassium bichromate solution, with 10 cc. sulphuric acid, reduced with sulphurous acid, and proceeded as before, using caustic soda as described.

With 5 grms. of iron salt 19.7 cc. bichromate were taken—

$$13.95 \times 5 = 69.75 - 50 = 19.75,$$

which is quite correct. This I verified repeatedly.

In its application, however, to chromium irons we have still to deal with what is left insoluble in sulphuric acid.

Dr. Clark mentions that A. Zeigler suggests fusing the chromium iron with caustic soda and nitrate of potash, and I have found this to be a very satisfactory method, one fusion of the insoluble being quite sufficient.

The best method of proceeding I find is as follows: Dissolve the chrome iron, as described, in sulphuric acid, and filter. The filtrate is treated with permanganate, as I have already described, and using soda.

The insoluble matter is dried and ignited in a porcelain crucible, then fused with say 6 grms. caustic soda and a little nitrate of potash in a platinum or silver crucible. It is fused perhaps for fifteen minutes, and is then dissolved in water, filtered and washed, and the filtrate made acid with hydrochloric acid, reduced with sulphurous acid, and the oxide of chromium precipitated with ammonia, filtered, dissolved in dilute sulphuric acid, and treated with permanganate like the original solution, or may be added to it.

In the case of a complete analysis, the fusion will be very useful, in which case you must fuse the original iron. It will be found, too, that the permanganate process is really the best way of dealing with the oxide of chromium precipitate. The old method is to weigh the precipitate as oxide of chromium, but this gives far too high results. Otherwise the oxide of chromium is not so easily dealt with as might be supposed.

In one sample I got results as follows :—

| Using .5 Grms.          | Solution, with<br>7 Grms. Iron Salt. | Fused Insoluble,<br>with 1 Grm.<br>Iron Salt. | Chromium. |
|-------------------------|--------------------------------------|-----------------------------------------------|-----------|
|                         | cc.                                  | cc.                                           | Per Cent. |
| First experiment . . .  | 6.0                                  | 12.0                                          | 58.40     |
| Second experiment . . . | 5.7                                  | 11.90                                         | 58.63     |

In another sample, said to contain 28 per cent. of chromium, the results were—

| Using .5 Grms.          | Solution, with<br>4 Grms. Iron Salt. | Fused Insoluble,<br>with 1 Grm.<br>Iron Salt. | Chromium. |
|-------------------------|--------------------------------------|-----------------------------------------------|-----------|
|                         | cc.                                  | cc.                                           | Per Cent. |
| First experiment . . .  | 15.6                                 | 11.40                                         | 26.67     |
| Second experiment . . . | 15.4                                 | 11.50                                         | 26.82     |

In another sample, said to contain 8 per cent. chromium, the results were as follows :—

5 grms. were treated as described, using soda ; and with 2 grms. iron salt 12.7 cc. were consumed—

$$13.95 \times 2 = 27.90 - 12.7 = 15.20$$

$$15.2 \times 2 = 30.4 \times .312 = 9.48 \text{ per cent. chromium.}$$

This was repeated, but without soda. With 2 grms. iron salt 15.4 cc. were taken—

$$27.90 \times 15.4 - 12.5 \times 2 = 25.00$$

$$25 \times .312 = 7.8 \text{ per cent. chromium.}$$

The precipitated oxide of manganese was now washed from the filter and treated with soda and filtered, the chromium being determined in the filtrate. With 1 gram. iron salt 11.2 cc. were taken—

$$13.95 - 11.2 = 2.75 \times .362 = .858 \times 21.71$$

$$7.80 + 1.71 = 9.51 \text{ per cent. chromium.}$$

Another sample gave respectively—

$$50.58 - 50.63, \text{ and } 50.63 \text{ per cent. chromium.}$$

These samples were kindly given me by Messrs. Hadfield.

The amount of insoluble matter is not, of course, a matter of importance if it has to be fused at all, and will, of course, depend as much on the fineness of the sample as on the percentage of chromium.

For determining iron, &c., fusing with caustic soda and nitrate of potash is very convenient, and two fusions will usually be found sufficient when treating the iron itself.

I need not say that these figures do not represent all the work I have done on the matter; they are typical, however, of a great deal of it, and show clearly the cause of the error in high or rich chromium irons, and also the ease with which the chromium can be separated from the precipitate by means of a soda solution. It has not, I may say, lengthened the process in any way, as the treatment with soda leaves the precipitate quite granular, and it filters much more rapidly than from the acid solution.

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## ON METHODS OF DETERMINING CHROMIUM,

WITH

NOTES ON THE DISTRIBUTION OF CHROMIUM  
IN BRITISH IRONS.

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By J. E. STEAD.

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In these days when manual labour is so largely being replaced by machinery, and when the processes of production of iron and steel are so rapid, it is imperative that, in order to be of the greatest use, the metallurgical chemist in the laboratories of our iron and steel works must improve his analytical methods, and endeavour to obtain strictly accurate results in the very shortest period of time.

In days of old, in the beginning, when analyses were not in great demand, it was thought not at all bad work if a complete analysis of steel was finished in a week; now the work is done in a single day; and I am confident of this, that the analyses made to-day are of greater accuracy, and therefore greater value, than those made thirty years ago by the laborious and tedious methods then in use.

The methods used for the determination of chromium at that time were essentially gravimetric, and it took several days to make a single estimation.

In 1871, Dr. Clark of Glasgow published a new method for the volumetric determination of chromium in chrome ores,\* by which means the amount of chrome was ascertained in a few hours.

At that time chrome steels and irons were not in use, and the method of Dr. Clark was not applied or applicable to the analysis of such material; but quite recently that gentleman has published a method specially adapted to the use of the iron and steel manufacturer.†

\* *Chemical News*, vol. xxiv. pp. 286-304.

† *Journal of Society of Chemical Industry*, vol. xi. p. 501.

For details of the process reference must be made to the original article.

In brief, however, the process depends on the conversion of the chrome steels or alloys into sulphides, by heating them in a porcelain tube in an atmosphere of carbon di-sulphide, and subsequently into oxide by calcination in a muffle in an atmosphere of air, after which they are ground to powder and mixed with four times their weight of a mixture of magnesia and sodium-hydrate (5 parts  $MgO$  and 3 parts  $NaHO$ ), and the mixture is roasted for half an hour, by which treatment the greater part of the chromium is oxidised to chromic acid. This is washed out with water, and the insoluble residue is again ground to powder and re-roasted, with an additional quantity of the magnesia mixture, and the calcined frit is again washed with water.

The mixing, calcination, and washing is repeated a third time, to ensure the complete separation of the last traces of chrome.

The combined filtrates now contain the whole of the chromium in the state of chromic acid, and possibly some manganese as manganate of soda.

To separate the manganese, Dr. Clark boils with peroxide of hydrogen, which precipitates it as peroxide.

By filtration, a clear filtrate, containing no oxidising substance other than chromic acid, is obtained.

Sulphuric acid and a known quantity in excess of a ferrous salt is now added.

The amount of iron not oxidised by the chromic acid is determined by a standard solution of bichromate of potash, and the iron oxidised by the chrome is in this way obtained, which, multiplied by 0.3119, gives the amount of chromium in the quantity of the material operated upon.

The accuracy of this method no one need question ; but judged from a works analyst's point of view, it is a little tedious, and commands rather more time and attention than he could wish.



with permanganate of potash when the method is worked in the manner described?

To answer the first question two samples of steel, one containing about 1·5 per cent. chromium, and the other about 5·5 per cent. chromium, were digested with dilute sulphuric acid, and when all action had terminated, the small amounts of black residue were filtered off and thoroughly washed, and after burning off the papers in a muffle, they were examined for chromium with the following results:—

|                 |   |   |               |                             |
|-----------------|---|---|---------------|-----------------------------|
| Chrome in steel | . | . | 1·5 per cent. | 0·040 per cent. in residue. |
| „               | „ | . | 5·5 per cent. | 0·152 per cent. „           |

The next question which arose was, whether or not this residue is made soluble on boiling it with permanganate. In order to settle this point, after dissolving the steels in sulphuric acid, the process was carried forward to the second stage, but instead of filtering off the peroxide of manganese, it was removed by the addition of an excess of sulphurous acid, after which any unaltered residue was filtered off and examined as before.

This time no chromium was found insoluble in the first steel, and only 0·016 per cent. in the second.

It would appear, therefore, that in steels containing little chromium, sulphuric acid jointly with permanganate of potash effects complete solution, but that with alloys a little chrome still escapes.

As chrome steels rarely contain more than 1·5 per cent. chromium—the amount usually present being, as a rule, much less than that quantity—we may assume that in testing such material by this method in the past none has escaped solution.

As rich ferro-chromes are exceedingly difficult, if not impossible, to dissolve in acid, the Galbraith method is therefore inapplicable for the analysis of such material.

The question as to whether all the soluble chrome is oxidised by permanganate was answered by the following experimental results.

To several portions of pure ferrous sulphate, containing 2 grammes of iron, was added various quantities of chromium in bichromate of potash.



quantity added in excess, the greater the amount of chromic acid which will be obtained in solution.

It is probable that the peroxide of manganese in precipitating carries down with it a portion of the chromium which thus escapes detection.

As to what really does occur, has not yet been investigated.

It would appear, then, that when all known precautions are taken, the Galbraith process yields about 97·7 per cent. of the total chromium.

Mr. Galbraith may work his process in such a way as to obtain the whole of it. I cannot, however, obtain more.

In testing steels containing 1 per cent. of chromium, the loss of 2·3 per cent. is equal to 0·023 per cent., and the chromium found equal to 0·977 per cent.

In steels containing 5·50 per cent., a loss of 2·3 per cent. would reduce the chromium found to 5·37 per cent.

#### A NEW MODIFICATION OF THE ACID PERMANGANATE PROCESS.

After studying and working with Galbraith's process, a successful attempt was made to destroy or remove the insoluble peroxide so as to avoid filtration, and thus to simplify the determination.

Hydrochloric acid when of great strength acts upon chromates, chromous salts and free chlorine resulting; but it was found that a dilute solution of acid in water may be boiled with chromates without change, and that such acid will, on boiling, completely destroy or dissolve peroxide of manganese before attacking the chromates, chloride of manganese and free chlorine resulting, and that the whole of the chlorine, by energetic boiling, can be rapidly removed from the solution.

The same solution of hydrochloric acid also rapidly destroys permanganate of potash.

Based on these facts a modified permanganate process has been worked out in my laboratory.

In the first instance, if the amount of chrome is high after solution of the steel in sulphuric acid, the residue is filtered off and washed, the clear filtrate is boiled, and to the boiling solution (which should measure about 300 cc.) is added a saturated solution



water added, and, after boiling for ten minutes, 40 cc. of strong hydrochloric acid, mixed with 40 cc. of water, was poured into the solution, and the boiling continued till the brown peroxide had just disappeared; 150 cc. boiling water was then added, and the boiling continued till about 100 cc. of water had evaporated.

The solution was now free from chlorine.

50 cc. of ferrous sulphate, containing by titration with bichromate of potash 0.567 gramme of iron in the ferrous state, was now added to the solution, and the amount remaining unoxidised titrated with the following results, viz.—

|                                         |                           |
|-----------------------------------------|---------------------------|
| Iron added . . . . .                    | 0.567 grammes.            |
| Iron not oxidised . . . . .             | 0.217 "                   |
| Iron oxidised by chromic acid . . . . . | 0.350                     |
| 0.35 + 0.3119 + 50 . . . . .            | 5.458 per cent. chromium. |

The residue prepared as before described oxidised 0.001 grms. of iron = 0.016 per cent. chromium.

|                              |             |
|------------------------------|-------------|
|                              | Per Cent.   |
| Chrome in solution . . . . . | 5.458       |
| Chrome in residue . . . . .  | 0.016       |
| Total percentage . . . . .   | <hr/> 5.474 |

The same steel tested by Galbraith's method, without filtering off the residue, gave 5.30 per cent., and 5.28 per cent. chromium.

We now pass on to consider another method, which is based on known facts in chemical science, and is a mixture of several methods rolled into one, and which may be called the

#### HYPO-ACETO VOLUMETRIC METHOD.

This method has been worked out in my laboratory, and depends on the fact that chromium oxide is totally precipitated as phosphate from iron solutions which contain sufficient phosphoric acid, when they are boiled with hyposulphite of soda, and after the excess of sulphur di-oxide has been boiled off with acetate of ammonia or soda.

The precipitate so formed is simply filtered off, slightly washed, and is afterwards dried and burnt off, pounded, mixed, and calcined with about ten times its weight of the tribasic reagent before described.



The heat best adapted for the calcination being a bright red, such as is obtained at the back of a Griffin's muffle furnace when the door is closed.

In from ten minutes to half an hour all the chromium will be converted into chromate.

The mixture is calcined in platinum capsules or crucibles, and no stirring or attention whatever is required, and the strongest heat may be applied directly.

The crucible is then removed, and when cold the mass will be found either slightly sintered together or as loose powder.

This mass is transferred to a beaker, dilute hydrochloric acid added, and the crucible is rinsed out into the beaker with a little more hydrochloric acid, and afterwards with water, care being taken not to have at any time more than one-fifth of the volume of strong acid.

Boiling water is now added to make a total volume of 200 cc., and the solution is boiled to free from any free chlorine which might possibly have been formed by decomposition of manganate.

The resulting solution is examined for chromic acid in the manner previously described, and the iron oxidised determined.

Instead of hydrochloric acid sulphuric acid may be used, but in that case the magnesia should be substituted for the calcic reagent.

When vanadium is present hydrochloric acid is inadmissible, for reasons presently to be explained.

This method, when applied to known quantities of chromium, gave the following results :—

| No.       | Chromium. |        |
|-----------|-----------|--------|
|           | Added.    | Found. |
| 1 . . . . | 0.0032    | 0.0030 |
| 2 . . . . | 0.0320    | 0.0315 |
| 3 . . . . | 0.1280    | 0.1276 |
| 4 . . . . | 0.1600    | 0.1601 |
| 5 . . . . | 0.1600    | 0.1594 |

The slight loss shown above is probably due to a slight solubility of the phosphate of chromium in the boiling water used to wash it.

By using water containing 2 per cent. nitrate of ammonia to wash the precipitates instead of water, the following results were obtained :—

| No.         | Chromium. |        |
|-------------|-----------|--------|
|             | Added.    | Found. |
| 1 . . . . . | 0·0032    | 0·0032 |
| 2 . . . . . | 0·0320    | 0·0321 |
| 3 . . . . . | 0·0640    | 0·0641 |

The following directions for the working of this method when determining chromium in steel will make it clear.

Dissolve 2 grms. in either strong hydrochloric or dilute sulphuric acid, and, without filtering, nearly neutralise the free acid with caustic soda solution (1 to 50), boil the iron solution, which should have a volume of 300 cc., and add 10 cc. of phosphate of soda solution (1 to 20) and about one ounce of solid hyposulphite of soda, and continue to boil till free from sulphur di-oxide, then add 20 cc. of strong acetate of soda or ammonia and boil for five minutes longer, then filter off and wash on to the filter the precipitate with a boiling 2 per cent. solution of ammonium nitrate, and wash it four times with this solution.

Now dry it and burn off at a gentle red heat, when the residue will be left as a slightly coherent loose mass most readily reduced to exceedingly fine powder in a glass mortar.

This is ground up with ten times its weight (an excess makes no difference) of the tribasic reagent, and the mixture is returned again to the crucible and is calcined at bright redness for half an hour.

It is then removed cooled, dissolved in about 30 cc. hydrochloric acid and 150 cc. water; the liquid is then boiled for ten minutes, after which it is ready for titration.

The steel before referred to, by this method gave :—

|                 |  | Chromium.<br>Per Cent. |
|-----------------|--|------------------------|
| No. 1 . . . . . |  | 5·474                  |
| No. 2 . . . . . |  | 5·458                  |
| No. 3 . . . . . |  | 5·464                  |

The filtrate from the hypo and acetate precipitates were oxidised,











In each case the chromic acid was determined with a ferrous solution and bichromate of potash.

The following determinations were made by the Hypo-Aceto Volumetric method, titrating with permanganate in sulphuric acid solution.

CHROMIUM IN BRITISH IRON AND STEEL, ETC.

The results were obtained on working on from 5 to 10 grammes of material :—

| <i>Pig Iron.</i>                                                                 |   |   |   |   |   |   | Chromium.<br>Per Cent. |
|----------------------------------------------------------------------------------|---|---|---|---|---|---|------------------------|
| District.                                                                        |   |   |   |   |   |   |                        |
| Glengarnock Forge                                                                | . | . | . | . | . | . | 0·016                  |
| 1. Do. Basic                                                                     | . | . | . | . | . | . | 0·028                  |
| 2. Do. Do.                                                                       | . | . | . | . | . | . | 0·035                  |
| Carnforth Hæmatite                                                               | . | . | . | . | . | . | 0·013                  |
| Wellington No. 1.                                                                | . | . | . | . | . | . | 0·058                  |
| Holwell                                                                          | . | . | . | . | . | . | 0·120                  |
| Lincolnshire No. 3.                                                              | . | . | . | . | . | . | 0·017                  |
| Forest of Dean No. 3.                                                            | . | . | . | . | . | . | 0·008                  |
| Silverdale                                                                       | . | . | . | . | . | . | 0·011                  |
| Lilleshall Cold Blast                                                            | . | . | . | . | . | . | 0·010                  |
| Welsh Foundry                                                                    | . | . | . | . | . | . | 0·014                  |
| 1. Cleveland No. 3.                                                              | . | . | . | . | . | . | 0·051                  |
| 2. Do.                                                                           | . | . | . | . | . | . | 0·064                  |
| 3. Do.                                                                           | . | . | . | . | . | . | 0·069                  |
| 4. Do.                                                                           | . | . | . | . | . | . | 0·059                  |
| Cleveland Hæmatite, from Spanish Ore                                             | . | . | . | . | . | . | 0·008                  |
| 2. Do.                                                                           | . | . | . | . | . | . | Nil                    |
| 1. Cleveland Basic iron made with Cleveland ore, manganese ore, and forge conder | . | . | . | . | . | . | 0·110                  |
| 2. Do. Do.                                                                       | . | . | . | . | . | . | 0·096                  |
| 3. Do. Do.                                                                       | . | . | . | . | . | . | 0·085                  |

*Steels.*

| District.                          |   |   |   |   |   |   | Chromium.<br>Per Cent. |
|------------------------------------|---|---|---|---|---|---|------------------------|
| Sheffield from Cumberland Hæmatite | . | . | . | . | . | . | 0·006                  |
| Swedish                            | . | . | . | . | . | . | Nil                    |
| 1. Cleveland Basic Steel           | . | . | . | . | . | . | 0·010                  |
| 2. Do. Do.                         | . | . | . | . | . | . | 0·008                  |
| 3. Do. Do.                         | . | . | . | . | . | . | 0·012                  |





| Description.               | Pig.      | At Com-<br>mencement of<br>the Blow. | Before the<br>After Blow. | After the<br>After Blow. |
|----------------------------|-----------|--------------------------------------|---------------------------|--------------------------|
|                            | Per Cent. | Per Cent.                            | Per Cent.                 | Per Cent.                |
| Chrome in metal . . . .    | 0·035     | 0·022                                | 0·016                     | 0·018                    |
| Do. in accompanying slag . | ...       | 0·038                                | 0·102                     | 0·100                    |

VANADIUM IN PIG IRON.

The methods of determining vanadium are receiving careful consideration, and it is hoped that before long I shall be able to place before this Institute the results obtained.

So far as I have gone it has been found that in British pig irons it invariably accompanies chromium, also that a considerable proportion of that present in pig iron is not obtained in solution on treating with hydrochloric and sulphuric acids.

The following results will be of interest, viz.:—

| Description.                | Vanadium. |            |           |
|-----------------------------|-----------|------------|-----------|
|                             | Soluble.  | Insoluble. | Total.    |
|                             | Per Cent. | Per Cent.  | Per Cent. |
| Clarence Pig Iron . . . .   | 0·120     | 0·063      | 0·183     |
| Cleveland Pig Iron . . . .  | 0·100     | 0·162      | 0·262     |
| Cleveland Pig Iron . . . .  | 0·048     | 0·213      | 0·261     |
| Holwell Pig Iron . . . .    | 0·076     | 0·110      | 0·186     |
| Lincolnshire Pig Iron . . . | 0·080     | 0·088      | 0·168     |

The vanadium is most readily detected qualitatively in the insoluble residue by heating it with the magnesia mixture or the tribasic reagent, extracting with water, and after filtering and acidulating with sulphuric acid and adding a few drops of peroxide of hydrogen.

If vanadium is present, the solution assumes a deep red colour, which is dissipated on boiling.

## VOTES OF THANKS.

The PRESIDENT said it was now his duty to move the following resolution :—"That the thanks of the Iron and Steel Institute be and are hereby tendered to the President, Council, and Secretary of the Institution of Civil Engineers for the use of their rooms, and for the facilities otherwise accorded for the present meeting.

Mr. JEREMIAH HEAD seconded the motion, which was unanimously agreed to.

Sir HENRY BESSEMER said there was one other duty they had to perform, and he was sure it would be a pleasurable one. He rose to propose :—"That the cordial thanks of the Iron and Steel Institute be and are hereby tendered to the President for his admirable conduct in the chair."

Mr. WILLIAM ROBERTS seconded the motion, which was carried unanimously.

The PRESIDENT said he heartily thanked the members for their acknowledgment of his services, and he hoped they would regularly attend the meetings, volunteer papers, and contribute to the discussions.

*OBITUARY.*

WILLIAM GEORGE AINSLIE, born in 1832, in India, was educated at Sedbergh School. He was originally in the service of the East India Company, and at the time of his death was senior partner in the iron and steel manufacturing firm of Messrs. Harrison, Ainslie & Co., of Ulverston, and chairman of the North Lonsdale Iron and Steel Company, Limited, of the same place. Notwithstanding his many business engagements, he found time to interest himself in public affairs. He was a magistrate for Lancashire, and in 1885 and 1886 member of Parliament for the North Lonsdale division of that county. When in Parliament, he took an active part in the promotion of the Pig Iron Warrants Bill. He took great interest in the Volunteer movement, and formerly held a commission as captain in the 37th Lancashire Volunteers. He was an original member of the Iron and Steel Institute, and was present at the inaugural meeting in London on June 23, 1869. Mr. Ainslie died in February last, and was thus sixty-one years of age.

EDWARD CARR, who was elected a member of the Iron and Steel Institute in 1883, died in March last at the early age of forty-seven. He had been connected with the iron trade for nearly twenty years, and at the time of his death was acting as the London representative of Messrs. Ibbotson Brothers & Co. of Sheffield.

✓ EDWARD ALFRED COWPER, son of Edward Cowper, the improver of the printing-press, and Professor of Engineering at King's College, was born on December 10, 1819. He was apprenticed in 1834 for seven years to Mr. John Braithwaite of London, and in 1846 he was engaged by Messrs. Fox & Henderson of Birmingham. In 1851 he was occupied with the contract drawings for the buildings of the Great Exhibition, and in that year started practice as a consulting engineer in London.

Mr. Cowper designed the roof of the Birmingham Railway Station, the first large-span (211 feet) station roof constructed. He was a fertile







regenerators, the placing of the gas-producer close to the furnace, and a simplification and economy in construction.

At the last meeting of the Iron and Steel Institute, Mr. Head read a paper entitled "Notes on Puddling," which is published in this volume. Although for years past Mr. Head has suffered from bad health, and was attacked by influenza three years ago, his sudden death from pneumonia, which took place after six days' illness, was a shock and surprise to all who knew him. He died on July 14, and was interred at St. Mary's Cemetery, Kensal Green, on the 20th. Mr. Head was a Fellow of the Geological Society, and a member of the Institution of Civil Engineers. He was elected a member of the Iron and Steel Institute in 1884.



SECTION II.

*NOTES ON THE*

*PROGRESS OF THE HOME AND FOREIGN*

*IRON AND STEEL INDUSTRIES.*

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EDWIN J. BALL, PH.D.

BENNETT H. BROUGH, Assoc. R.S.M.

# IRON ORES.

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### I.—OCCURRENCE AND COMPOSITION.

**Theories of the Origin of Iron Ores.**—Mr. H. V. Winchell\* gives the following classification of the theories of the origin of iron ores:—

*A. Mechanical:—*

*a.* Extra-terrestrial or cosmical: 1. Meteoric fall.

*b.* Terrestrial: 1. Subterranean, eruption in dykes or accompanying basaltic flows; 2. Superficial action, (a.) violent abrasion and transport; (b.) ordinary erosion ( $\alpha$ . concentration of iron sands;  $\beta$ . oceanic sedimentation).

*B. Chemical:—*

*a.* Changes *in situ*: 1. Change in the kind or quantity of iron already present in the rocks, (a.) alteration of diffused ferric oxide into ferrous carbonate; (b.) metamorphism of bog ore; (c.) metamorphism of lake ore; (d.) alteration of ferrous carbonate or sulphide into ferric oxide; 2. Change in the kind or quantity of other minerals; (a.) substitution of iron oxide for some non-ferriferous mineral; (b.) concentration by removal of the other constituents; (c.) electro-telluric action.

*b.* Removal by chemical action and subsequent deposition: 1. By action of heat (sublimation); 2. By action of water; (a.) in drainage basins, by oceanic precipitation, or as a secondary product of the decomposition of basic rocks or of pyrites; (b.) in the rocks, by saturation of porous strata, or by infiltration into cavities; (c.) deposited by springs.

**The Iron Ores of Great Britain and Ireland.**—In a volume covering 430 pages, Mr. J. D. Kendall† gives a systematic and careful

\* *The American Geologist*, vol. x. pp. 277-278.

† "The Iron Ores of Great Britain and Ireland." London, 1893.



Red hæmatite from the Trofaiach ironworks. 5. Magnetite from the same works :—

| Description.                 | 2.            | 3.            | 4.            | 5.            |
|------------------------------|---------------|---------------|---------------|---------------|
|                              | Per Cent.     | Per Cent.     | Per Cent.     | Per Cent.     |
| Ferrous oxide . . . .        | 46·41         | 0·50          | 3·98          | 29·08         |
| Ferric oxide . . . .         | 3·86          | 66·31         | 60·43         | 52·50         |
| Manganous oxide . . . .      | 3·50          | 3·10          | 3·15          | ...           |
| Copper . . . . .             | trace         | 0·01          | 0·07          | ...           |
| Alumina . . . . .            | ...           | 1·59          | 0·64          | trace         |
| Lime . . . . .               | 2·10          | 1·50          | 2·40          | 2·50          |
| Magnesia . . . . .           | 3·61          | 0·77          | 2·63          | 0·30          |
| Silica . . . . .             | 5·10          | 14·70         | 8·35          | 4·75          |
| Carbonic anhydride . . . .   | 34·80         | ...           | 3·60          | 9·10          |
| Sulphuric anhydride . . . .  | 0·92          | ...           | 4·25          | 0·86          |
| Phosphoric anhydride . . . . | 0·06          | 0·21          | 0·06          | 1·19          |
| Loss on ignition . . . . .   | ...           | 11·00         | ...           | ...           |
| Barytes . . . . .            | ...           | ...           | 7·42          | ...           |
| Water . . . . .              | ...           | ...           | 2·80          | ...           |
| Organic matter . . . . .     | ...           | ...           | 0·21          | ...           |
| <b>Totals . . . . .</b>      | <b>100·36</b> | <b>100·19</b> | <b>100·00</b> | <b>100·28</b> |
| Iron . . . . .               | 38·80         | 47·15         | 45·40         | 59·31         |
| Manganese . . . . .          | 2·72          | 2·40          | 2·27          | ...           |
| Phosphorus . . . . .         | 0·02          | 0·08          | 0·02          | ...           |
| Sulphur . . . . .            | 0·37          | 0·27          | 1·70          | 0·34          |

**Luxemburg Iron Ore.**—In the neighbourhood of Esch there are four deposits of brown hæmatite. The upper one is rarely worthy of exploitation, as it contains a large percentage of silica. Below this, at varying depths, follows a bed of red ore 6 feet thick, then, at a farther depth of 36 or 40 feet, follows another bed from 8 to 16 feet of a grey ore, and at a still greater depth another bed of a brown ore from 8½ to 10 feet thick. The beds are horizontal, or only very slightly inclined. The percentage of iron in these three lower beds of ore varies from 36 to 39 per cent. The cost of the ore f.o.b. at Esch is only 2s. a ton. The number and thickness of these beds of minette ore decreases from the north towards the south. According to J. G. Jungner,\* estimates place the duration of the German Lorraine ore deposits at 750 years, the annual output remaining as at present, while the Luxemburg deposits will last for 100 years.

**Iron Ore in Poland.**—In the course of an elaborate report on the industrial resources of Western Russia, J. Couharevitch † gives full details of the occurrence of iron ore. The Carboniferous strata include

\* *Jernkontorets Annaler*, vol. xlv. pp. 156–163.

† *Revue Universelle des Mines*, vol. xix. pp. 265–385.







have been found among the quartzites of the La Cloche region, but none appears to be sufficiently extensive to justify mining operations. The ores are free from titanium, phosphorus, and sulphur, and it is to be hoped that further explorations among these rocks may bring to light larger masses of iron ore.

Thin veins of good magnetite, accompanied by quartz, occur in the red hornblende granite near Cartier Station and on the Spanish River. The granitic districts, however, do not appear to be promising for iron ores.

On Iron Island, in Lake Nipissing, small masses of specular iron are common to most of the rocks in the island, and in the crystalline limestone there is a very great display of it. In the Huronian iron-bearing region of Lake Superior the ores have two different modes of occurrence. In the one case they are associated with hornblendic or chloritic schists, which appear to belong near the base of the system, and in the other they occur with fine-grained siliceous and jaspery rocks. The magnetite of the Aticokan region is an example of the first, and that of Hunter's Island and Kaministiquia River of the second.

Mr. T. D. Ledyard \* gives the following analyses from various sources of magnetic iron ore from the Belmont Mine in Ontario :—

| Iron.              | Phosphorus.        | Sulphur.          | Titanic Anhydride. | Silica.           |
|--------------------|--------------------|-------------------|--------------------|-------------------|
| Per Cent.<br>65·10 | Per Cent.<br>0·005 | Per Cent.<br>0·07 | Per Cent.<br>0·04  | Per Cent.<br>3·83 |
| 66·23              | 0·013              | 0·016             | ...                | 3·88              |

In various localities near Devil's Lake considerable quantities of ore have been found with contents as follows :—

| Iron.              | Phosphorus.        | Sulphur.           | Titanium. |
|--------------------|--------------------|--------------------|-----------|
| Per Cent.<br>62·26 | Per Cent.<br>0·009 | Per Cent.<br>0·052 | None.     |
| 69·25              | 0·012              | 0·038              | Trace.    |

Mr. W. Molin † gives the following analysis of magnetic iron ore from a large deposit situated at Belmont, about a hundred miles east of Toronto :—

\* *Engineering and Mining Journal*, vol. lv. p. 322.  
† *Ibid.*, vol. liv. p. 484.





| Locality.               | Magnetite. | Hæmatite. | Siliceous Matter. |
|-------------------------|------------|-----------|-------------------|
|                         | Per Cent.  | Per Cent. | Per Cent.         |
| Manukau, Auckland . .   | 60·20      | 37·9      | 1·90              |
| Interior of Otago . . . | 86·32      | ...       | 13·68             |
| Lake Wakatipu, Otago .  | 96·11      | ...       | 3·89              |
| Nelson mineral belt . . | ...        | 90·6      | 7·60              |

In the Tertiary coal formation of Raglan, near Auckland, brown ore is found with the following composition :—

|                       |                     |                   |        |           |
|-----------------------|---------------------|-------------------|--------|-----------|
| Ferric Oxide.         | Oxide of Manganese. | Alumina.          | Lime   | Magnesia. |
| 72·69                 | 0·56                | 1·16              | 0·27   | 0·69      |
| Phosphoric Anhydride. | Sulphide of Iron.   | Siliceous Matter. | Water. |           |
| 0·70                  | trace.              | 6·30              | 17·63  |           |

A hydrated ferric oxide is found in large quantities on the surface near Collingwood, Nelson, and appears to be the capping of a pyritic vein. A sample gave :—

|               |            |       |           |                   |        |
|---------------|------------|-------|-----------|-------------------|--------|
| Ferric Oxide. | Manganese. | Lime. | Magnesia. | Siliceous Matter. | Water. |
| 62·68         | trace.     | 0·61  | trace.    | 23·47             | 13·24  |

Iron manufactured from this ore contained :—

|        |       |       |       |        |       |       |
|--------|-------|-------|-------|--------|-------|-------|
| Fc.    | Mn.   | C.    | Sl.   | Tl.    | P.    | S.    |
| 97·668 | 0·268 | 0·750 | 1·004 | trace. | 0·041 | 0·269 |

Close by this deposit is an abundant supply of pure limestone, and the Collingwood coal-mine is only five miles away. A similar deposit has been found at Mount Peel, Nelson. Spathic ore, of which a detailed analysis is given, is found in the Collingwood Colliery, and other pure spathic ores have been found in two other collieries. Some account is then given by the author of the various attempts that have been made to manufacture iron in the colony.

**The Menominee Iron Ore Range.**—According to Mr. D. Hulst,\* who gives a description of the geology and characteristics of the eastern portion of the Menominee Range, it appears that its productive portions are, to a certain extent, situated at or near points where the geological formation has been faulted, eroded deeply, or sharply folded. One of these features occurs in close proximity to the Iron Mountain and the mines at Pewabic, Quinnesec, Norway, Aragon, and elsewhere. The ore

\* Paper read before the Lake Superior Mining Institute; *Engineering and Mining Journal*, vol. lv. p. 366.







a guaranteed output of at least 150,000 tons per annum. On the property of the Kanawha and Hale Company the ore appears to lie in a kind of narrow gorge. For instance, of two test-pits sunk at a distance of 50 feet from each other, the one passes through 55 feet of ore, whilst the other is in green schist. This schist lies unconformably below the taconic rocks, and the ore is found in a depression between the two formations. The property known as the Mesabi Mountain has been leased on the basis of an annual output of 400,000 tons. In this and the Lone Jack properties, this pre-glacial gorge appears to have been excavated by a stream flowing in a westerly direction from the green schist ridge across the Lone Jack and Mesabi Mountain. This gorge then became filled with a kind of gravel consisting of round water-worn fragments of hard ore. The gorge was then covered with drift. At the bottom of this gravel-filled gorge is a stratified layer of light-coloured clayey matter, which varies in thickness from a few inches to 12 feet. Beneath this soft blue hæmatite is found.

Placing the cost of mining the ton of ore at 1s., and the royalty at 2s. 6d. per ton, the cost of the ton of ore delivered at Cleveland is a little over 12s. The contracts already made relate to an annual production of ore in this range of over one and a half million tons.

**Iron Ore from the Vermilion Range.**—Messrs. Pickands, Mather, & Co. give the following average analyses of the ore from various iron ore deposits in the Vermilion Range, which were mined in 1891 : \*—

| Description.       | Vermilion. | Soudan.   | Red Lake. | Minnesota. | Chandler. | Long Lake. |
|--------------------|------------|-----------|-----------|------------|-----------|------------|
|                    | Per Cent.  | Per Cent. | Per Cent. | Per Cent.  | Per Cent. | Per Cent.  |
| Iron . . . .       | 67·75      | 65·96     | 63·49     | 68·14      | 63·91     | 60·06      |
| Silica . . . .     | 1·58       | 2·27      | 5·00      | 1·30       | 5·10      | 7·20       |
| Phosphorus . . . . | 0·15       | 0·102     | 0·111     | 0·049      | 0·041     | 0·044      |
| Manganese . . . .  | 0·29       | 0·14      | 0·19      | trace      | 0·69      | 0·61       |
| Alumina . . . .    | 0·98       | 1·80      | 0·90      | 1·10       | 2·90      | 2·87       |
| Sulphur . . . .    | trace      | trace     | 0·026     | trace      | trace     | 0·043      |
| Magnesia . . . .   | trace      | 0·30      | 0·30      | 0·13       | trace     | 0·19       |
| Lime . . . .       | 1·00       | 0·54      | 0·71      | 0·56       | 0·37      | 0·31       |

The quantity of ore mined at the Chandler Mine in 1891 was 354,993 tons. The cost of mining and delivering at Cleveland is stated to be as follows :—

\* *Iron Age*, vol. li. p. 17.



**Iron Ore in Mexico.**—The iron ore deposits of Mexico are reviewed by Mr. R. T. Hill\* in the course of a discussion of the capabilities of that country as an iron-producer. At the present time, chiefly owing to difficulties of transport, the cost of even common castings is excessively high, but railways are now being built to a considerable extent. The Iron Mountain at Durango is one of the best known and largest of the many large deposits that have been discovered. The ore here consists of specular hæmatite and martite, and it averages 52 per cent. of metallic iron. Several other deposits have been studied by the author. Near Monclova, on the line of the Mexican International Railway, and three hundred miles nearer the coal supply, is one of the large deposits similar to that at Durango. It consists of an elongated mountain of hard blue limestone of Lower Cretaceous age, with enormous outcrops of ore some 1000 feet above the railway. Other similar deposits are found near Salome Botello, in the Sierra Carrissal, and also in the States on the Pacific coast. Ore has been smelted for several years near the coast in Catalan furnaces. Particulars of many of these deposits are given. In general, the deposits in the Northern States are in desert regions, where wood is scarce, but the southern State of Guerero is exceedingly well wooded. Several important coalfields have been discovered, notably that in Northern Coahuila, some sixty miles from Monclova and twenty miles from the Candeila ore. This coal is similar to that of the Rocky Mountain region. Anthracite is also reported on the Yaqui River of Sonora, and other coals are also mentioned. The probability of the use of Mexican iron ores is then discussed.

**Iron Ore from Cuba.**—Two analyses of Sigua iron ore, taken from a cargo consigned to America, have been published.† The results are as follows:—

| Fe.       | Cu.       | S.        | P.        | Al <sub>2</sub> O <sub>3</sub> . | CaO.      | MgO.      | SiO <sub>2</sub> . |
|-----------|-----------|-----------|-----------|----------------------------------|-----------|-----------|--------------------|
| Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent.                        | Per Cent. | Per Cent. | Per Cent.          |
| 65·85     | 0·008     | 0·037     | 0·015     | 0·80                             | 0·26      | 0·17      | 3·53               |
| 65·57     | ...       | 0·026     | 0·014     | 0·71                             | 0·62      | 0·11      | 1·40               |

The furnace analyses showed 66·61 per cent. of iron and 0·010 per cent. of phosphorus. A second cargo, analysed by Mr. A. S. M'Creath, showed 63·35 per cent. of iron and 0·014 of phosphorus.

\* *Engineering Magazine*, vol. iv. pp. 743–753, with map, and *American Journal of Science*, vol. xlv. pp. 111–119.

† *Iron Age*, vol. l. p. 1049.









| No.  | Fe.       | Ni.       | Co.       | Cu.       | P.        | C.        | Insoluble. |
|------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
|      | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent.  |
| I.   | 91·36     | 7·77      | 0·18      | 0·02      | 0·03      | ...       | 0·14       |
| II.  | 91·18     | 7·63      | 0·66      | 0·01      | 0·03      | ...       | 0·49       |
| III. | 89·48     | 9·30      | 0·88      | 0·02      | 0·32      | ...       | ...        |
| IV.  | 91·07     | 7·77      | 0·66      | 0·01      | 0·02      | ...       | 0·47       |
| V.   | 87·88     | 10·40     | 0·72      | ...       | 0·92      | 0·08      | ...        |
| VI.  | 37·24     | 62·01     | 0·72      | 0·28      | 0·15      | ...       | ...        |
| VII. | 81·54     | 17·74     | 1·26      | ...       | 0·11      | ...       | 0·05       |

I. From Schwetz an der Weichsel, Prussia ; II. from Ivanpah, S. Bernardino County ; III. Chupaderos, Mexico ; IV. Misteca, Mexico ; V. Glorieta Mountain ; VI. Octibbeha County ; VII. from Babbs Mill, Green County.

In those instances in which these meteorites had been already analysed the author gives the results that were previously obtained.

It is stated by E. Cohen \* that copper, in small quantities, is of frequent occurrence in meteorites ; but in five meteorites examined no arsenic, antimony, zinc, manganese, or chromium could be detected. The following are some analyses :—

| Description.   | Fe.       | Ni.       | Co.       | Cu.       | P.        | C.        |
|----------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Glorieta . .   | 87·95     | 10·41     | 0·72      | ...       | 0·92      | ...       |
| Chupaderos . . | 89·48     | 9·30      | 0·88      | 0·02      | 0·32      | ...       |
| Toluca . .     | 90·70     | 8·41      | 0·61      | 0·01      | 0·27      | ...       |
| Misteca . .    | 91·50     | 7·81      | 0·66      | 0·01      | ...       | 0·02      |
| Wichita . .    | 89·36     | 8·62      | 0·72      | 0·02      | 0·97      | 0·31      |
| Magura . .     | 92·91     | 6·46      | 0·82      | 0·01      | 0·32      | 0·20      |

C. Friedel † describes the occurrence of diamonds in the meteoric iron of the Cañon Diablo.‡ The specimen found by Mr. Eckley Coxe was cut in two, and a portion was treated successively with hydrochloric acid, aqua regia, and hydrofluoric acid. The residue contained minute rounded grains, which exhibited all the properties of the diamond. The diamonds were not uniformly distributed in the specimen examined, but were concentrated in and about nodules of iron sulphide and phosphide.

C. Friedel,§ in reference to the existence of the diamond in the meteoric iron from the Cañon Diablo, made an experiment in which some carbon bisulphide was enclosed in a small hollow in the centre of a steel block, which was then raised to redness. The carbon bisulphide was decom-

\* *Annalen des k.k. Naturhistorischen Hofmuseums*, vol. vii. p. 101.  
† *Comptes Rendus de l'Académie des Sciences*, vol. cxv. pp. 1037-1041.  
‡ *Journal of the Iron and Steel Institute*, 1892, No. II. p. 126.  
§ *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 224.



1891 a mass of meteoric iron was turned up by a plough in Indian Valley township, Floyd County, Virginia. It weighs 31 lbs., and measures 11 by 8 by 5 inches. The surface is much corroded, and covered with a limonite crust. Analysis gave the following results:—

| Fe.   | Ni.  | Co.  | Cu.   | P.   | S.   | Si.   | Total. |
|-------|------|------|-------|------|------|-------|--------|
| 93·59 | 5·56 | 0·53 | trace | 0·27 | 0·01 | trace | 99·96  |

The structure of this meteorite is very interesting, as it lies between the so-called breccia and hexahedral irons. Some parts of the mass exhibit a granular structure identical with that of the Chattooga meteoric iron. It is a question whether the granular structure is the original structure out of which hexahedral particles were formed through recrystallisation, or whether it is due to the fact that this iron not being rich in nickel has a lack of crystallising power.

Mr. G. F. Kunz and Mr. E. Weinschenk \* state that a meteorite was found in the Sierra de la Ternerá, Province of Atacama, Chili. Although small, weighing but 650 grammes, it is undoubtedly the entire meteorite, as the unbroken original crust shows. Analysis gave the following results:—

| Fe.   | Ni.   | Co.  | P.   | Total. |
|-------|-------|------|------|--------|
| 83·02 | 16·22 | 1·63 | 0·00 | 100·87 |

This analysis places the iron near the Cape Iron group; but as the physical properties of this group of irons have been so little studied, it is impossible to say whether the structure coincides or not. The complete absence of phosphorus indicates that this meteorite is an exception to the rule in not containing the characteristic phosphor-nickel iron.

Mr. J. R. Gregory † describes a portion of meteorite in his possession brought from Youndegin, from which place several masses have already been obtained and described by Mr. L. Fletcher.‡ This mass weighs 382½ lbs.

Professor G. H. F. Ulrich § describes a meteoric stone found in 1879 near Invercargill, New Zealand. The specific gravity of the stone varied from 3·31 to 3·54. The chemical composition is approximately as follows:—Nickel-iron, 1; oxides of nickel and iron, 10; troilite, 6; enstatite, 39; olivine, 44. The examination is not yet finished, and details will be communicated later. The microscopic examination proved the stone to belong to the chondrites or, according to Wadsworth, to the

\* *American Journal of Science*, vol. xliii. pp. 425–426.

† *Nature*, vol. xlvii. pp. 90–92.

‡ *Journal of the Iron and Steel Institute*, 1887, No. II. p. 230.

§ *Proceedings of the Royal Society*, vol. liii. pp. 54–64, with six illustrations.



etched with dilute acid, the surface showed well-marked Widmannstätten figures. The meteorite consists essentially of kamacite, plessite, lamellæ of schreibersite, and some troilite. Its specific gravity is 7·67, and its composition is as follows:—

| Iron. | Nickel. | Cobalt. | Insoluble. |
|-------|---------|---------|------------|
| 91·32 | 5·88    | 0·81    | 1·04       |

Traces of copper and sulphur were also observed. The meteorite is of the rare schwetzite type described by the author in 1870.

A meteoric body of an estimated weight of 20 tons fell in the vicinity of Jiminez, Chihuahua, Mexico, at the end of 1892, and is now in the Mexican Museum. In its fall this enormous body struck the side of a cliff, uncovering a rich vein of silver ore.\*

**Chrome Iron Ore in Lower Silesia.**—B. Kosmann † describes the mode of occurrence of chrome iron ore at Tampadel in Lower Silesia. The ore is met with in veins, 23 feet in width, in serpentine, and contains inclusions of magnetite and spinel. Analysis gave results varying within the following limits:—

|               |   |   |   |   |   |   |   |   |   |          |
|---------------|---|---|---|---|---|---|---|---|---|----------|
| Chromic oxide | . | . | . | . | . | . | . | . | . | 35 to 42 |
| Magnesia      | . | . | . | . | . | . | . | . | . | 14 to 16 |
| Silica        | . | . | . | . | . | . | . | . | . | 4 to 6   |
| Ferrous oxide | . | . | . | . | . | . | . | . | . | 18 to 22 |
| Alumina.      | . | . | . | . | . | . | . | . | . | 18 to 22 |

**Manganese Ore in Wales.**—Mr. E. Halse, ‡ as addenda to a former paper § on the occurrence of manganese ore near the Arenigs, Merionethshire, gives several analyses, including one complete analysis of an ore containing 48 per cent. of metallic manganese.

## II.—IRON ORE MINING.

**Iron Ore Mining in Cleveland.**—After giving a short history of the discovery and development of iron ore in Cleveland, Mr. J. C. I'Anson || describes the drills used in this district. At the present time there are thirty-three Walker drills in use in the Cleveland mines. A

\* *The American Geologist*, vol. i. p. 217.

† *Zeitschrift der deutschen geologischen Gesellschaft*, vol. xlii. pp. 794-796.

‡ *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 167-168.

§ *Journal of the Iron and Steel Institute*, 1892, No. II. p. 329.

|| *Engineering*, vol. liv. pp. 653-654; vol. lv. pp. 241-243.





(1) Brown hæmatite mining at New Birmingham, Texas; (2) brown hæmatite mining near Anniston, Alabama; (3) magnetite mining at Cornwall, Pennsylvania; (4) magnetite mining at Mineville, New York; (5) red hæmatite mining at Iron Mountain, Missouri; and (6) red hæmatite mining at Tower, Minnesota. Full descriptions accompany the illustrations.

**Soft Ore Mining in the Lake Superior Region.**—Mr. P. Larsson\* describes the various methods in use for mining the ores known as soft ores in the Lake Superior district. These are the brown hæmatites and limonites of the Marquette range, the eastern ores in the Menominee range, all the Gogebic and Mesabi ores, and the Ely group of the Vermilion range. The methods are stripping and open pit work, rooming and timbering, filling and caving. Open work is used more or less in the whole of the district, although the depth is limited where the deposits dip above 45°. Steam shovels and locomotives are used for stripping. Probably it pays to strip the ore when its volume is equal to that of the barings. The second system of rooming with timbering is most extensively used. A common size is to make the rooms 20 to 24 feet wide, and the pillars somewhat less, with a length equal to the ore body. The rooms are worked from the bottom to the top of each lift, and are then filled with timbering. The system allows of a forced output, but the cost is heavy, and extensive cavings are likely to occur in large ore bodies. The cost is about one shilling per ton for timbering. Rock filling is sometimes preferable to timbering. It is most economical when shovelling is not required, that is, when the filling need not be close up to the bank of the slope. In the lower level of the Chapin mine this is done, as the ore will stand 20 feet wide over the whole width of the ore body. The system previously used at this mine of removing the ore in slices and filling up close to the back has been abandoned on account of the cost.

Two methods of caving are used. In one, stoping is commenced at the top of the lift under a gob roof; in the other, working is begun at the bottom under a soft roof of ore, which keeps coming down. The former method is largely used in Europe, especially in the North of England. The latter method was adopted eighteen months ago at the Chapin mine. A comparison is then given of the circumstances under which these two systems are most advantageously employed. In the

\* Paper read before the Lake Superior Mining Institute; *Engineering and Mining Journal*, vol. lv. p. 318.



that it shall be light enough to be easily handled, powerful enough to compete with compressed air-drills, simple in design, so that it can be repaired by an ordinary mechanic without electrical experience, capable of being soaked in mud or water without injury, and of enduring rough handling, and that it shall be incapable of burning out. The following elements of construction should, in the author's opinion, be avoided :— Travelling conductors, commutating or current shifting devices, sliding and spring contacts, cotton or other insulation liable to carbonisation, switches, lamination of the moving parts, close fittings, and joints liable to be impaired by wear.

The solenoid and plunger affords the simplest solution of the problem, and four methods of utilising these are discussed. In 1888 the author devised his system of working, in which two coils with three leads are used, and the coils are excited alternately. The number of times the coils are excited, and accordingly the number of blows of the drill, depends on the number of revolutions of the armature in the dynamo. Several plans for running the dynamo at a proper speed, of reducing the number of pulsations, and of taking the requisite current are described. The second plan is that of Van Depoele, and depends on a difference of phase in the two coils, three leads being also used. The third plan is that of Siemens and Halske, in which three coils are used. The centre coil is excited by a continuous current, and the outer ones by alternating currents of proper frequency. Four leads have to be used, but Van Depoele reduced these to three by the use of a rotating armature to send an alternating current through the end coils, and a unidirectional pulsating current of half the frequency through the centre coil.

Turning now to the construction of the drill itself, three types have been built, and of these illustrations are given. The first of these was worked in May 1891. In the latest form, the plunger is a solid steel forging, 4 inches in diameter, without the brass parts used in previous drills. The construction of the rotating gear and of the other parts follows generally that of the compressed air-drill. By means of a rotating drum and tracing pencil like a steam engine indicator, curves have been taken during the stroke of the drill to investigate the motion. These curves are discussed, and are compared with voltage curves in the coil.

**Electric Rock Blasting.**—Mr. W. L. Saunders \* describes at some length the various appliances used for electric blasting in America. The

\* *Transactions of the American Society of Civil Engineers*, vol. xxvii. pp. 529-564.



mineral that would admit of the application after roasting of electro-magnetic separation. One analysis showed this mineral to contain :—

|                     |                     |                     |                     |      |            |
|---------------------|---------------------|---------------------|---------------------|------|------------|
| FeCO <sub>3</sub> . | MnCO <sub>3</sub> . | CaCO <sub>3</sub> . | MgCO <sub>3</sub> . | ZnS. | Insoluble. |
| 79·65               | 1·28                | 2·36                | 13·80               | 0·71 | 2·12       |

By mechanical separation it was found impossible to effect a separation of the zinc blende with which this mineral was associated. In the process now adopted this material is roasted in shaft-kilns of rectangular shape, 3 feet 3 inches wide, 6 feet 6 inches long, and 10 feet 8 inches in height, with a knife-edge bottom, sloping at an angle of 45° to the two withdrawing openings. It was found, however, that this furnace showed a tendency in working to become clogged by slag adhering to its walls. This difficulty was overcome by building a narrow dividing wall up the centre of the kiln, dividing it into halves, for a distance of about 3 feet from the bottom. The outturn of such a kiln is about 7½ tons a day. The roasted material is powdered, and subjected to the action of the magnetic separators. The degree of success attained is shown in the following table :—

| Description.                      | Zinc.     | Iron.     |
|-----------------------------------|-----------|-----------|
|                                   | Per Cent. | Per Cent. |
| 50·5 tons original material . . . | 28·4      | 14·2      |
| 37·3 „ separated zinc ore . . .   | 34·0      | 9·8       |
| 13·2 „ separated iron ore . . .   | 18·5      | 23·7      |
| 85·4 „ original material . . .    | 25·8      | 19·8      |
| 48·4 „ separated zinc ore . . .   | 34·9      | 10·0      |
| 37·0 „ separated iron ore . . .   | 14·5      | 33·5      |

**Magnetic Separation.**—In describing magnetic separation, Mr. H. S. Chase \* says that more rapid work can be done dry, but cleaner and more perfect work wet. The repairs and renewals in the wet process are less, as the water acts as a lubricant and a cleaning medium.

**Shipping Iron Ore.**—Mr. J. Birkinbine† gives an account, with illustrations, of some of the larger docks in the United States, used for shipping and unloading iron ore. There are six shipping ports for the Lake Superior district, the most important being Escanaba, on Lake Michigan, where there are four docks. The railways in these docks are

\* *Technology Quarterly*, vol. v. pp. 64–69.  
† *Report of the Mineral Industries in the United States at the Eleventh Census*, 1890, Washington, 1892, pp. 26–29, with seven plates.

elevated from 35 to 47·5 feet above water level, and the ore is discharged from the trucks through drop-bottoms into pockets, from which it is loaded into the vessels through shoots. From the particulars given, it appears that the length of the docks varies from 600 to 1500 feet; the number of pockets in a dock from 78 to 250, and their capacity from 4000 to 33,000 tons. Illustrations are also given of the receiving docks, the largest of which is at Fairport, Ohio, with a frontage of 1 mile, and a width of 180 to 350 feet. The ore is stored to a height of 25 to 50 feet. About one-third of the ore is loaded direct on to the wagons during the shipping season, which lasts seven months, and the rest is stored. There are five general types of equipment of machinery at these docks for unloading the vessels.

## REFRACTORY MATERIALS.

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**The Fire-Clays of Alabama.**—Dr. E. A. Smith \* classes the fire-clays of Alabama under five heads according to their geological position. Clays of the crystalline schists or metamorphic formation are found in Coosa, Cleburne, and Randolph Counties. Cambrian and Silurian clays include the bauxites and kaolins of Cherokee and Calhoun Counties. Subcarboniferous clays occur at the base of the formation in close proximity to the underlying black shales. They approximate to halloysite, and have been worked in De Kalb County. The fourth class, or Cretaceous clays, are widely distributed in the Tuscaloosa formation over a large part of the state, an analysis of one specimen from Marion County being given below. Clays of the Tertiary formation occur in the Buhorstone division of the state in Choctaw County. The results of analyses of several samples are as follows :—

| Locality.                    | Silica.   | Alumina.  | Oxide of Iron. | Potash, Lime, Magnesia, &c. | Water.    | Undecomposed Material. |
|------------------------------|-----------|-----------|----------------|-----------------------------|-----------|------------------------|
|                              | Per Cent. | Per Cent. | Per Cent.      | Per Cent.                   | Per Cent. | Per Cent.              |
| Louina, Randolph County . .  | 37·29     | 31·92     | trace          | 0·72                        | 15·09     | 14·28                  |
| Jacksonville, Calhoun County | 44·60     | 38·92     | 0·78           | 1·03                        | 13·88     | 0·90                   |
| Chalk Bluff, Marion County   | 47·20     | 37·76     | 0·91           | traces                      | 14·24     | ...                    |
| Choctaw County . . . .       | 36·30     | 45·12     | 1·60           | 0·46                        | 6·60      | ...                    |

The great variety of the clays and their wide distribution offer a large field for selection.

**Bauxite.**—Bauxite was first discovered in 1821 in France, but, according to Mr. H. M'Calley,† did not come into commercial use until 1868. It occurs in Ireland, Austria, Asia Minor, and in the United States in Georgia, Alabama, Arkansas, and North Carolina. In Georgia the deposits only cover a small area of unknown depth. In Arkansas

\* *Proceedings of the Alabama Industrial and Scientific Society*, vol. ii. pp. 33–42.

† *Ibid.*, pp. 20–32.





| Locality.               | SiO <sub>2</sub> . | Al <sub>2</sub> O <sub>3</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | CaO.      | MgO.      | CO <sub>2</sub> . |
|-------------------------|--------------------|----------------------------------|----------------------------------|-----------|-----------|-------------------|
|                         | Per Cent.          | Per Cent.                        | Per Cent.                        | Per Cent. | Per Cent. | Per Cent.         |
| Near Metz . . . . .     | 3·20               | 0·21                             | 1·79                             | 35·65     | 15·97     | 43·18             |
| Huddlestons . . . . .   | 0·45               | ...                              | 0·47                             | 30·82     | 21·37     | 46·75             |
| Kiverton Park . . . . . | 3·99               | 0·37                             | 1·65                             | 29·12     | 20·96     | 43·60             |
| Grevenmacher . . . . .  | 1·20               | 2·00                             | ...                              | 29·00     | 20·00     | 47·00             |
| Beffort . . . . .       | 3·50               | 4·00                             | ...                              | 29·00     | 18·99     | 43·00             |
| Varigny . . . . .       | 4·10               | 3·00                             | 1·70                             | 28·30     | 18·60     | 44·20             |
| Dombrowa . . . . .      | 2·00               | 1·30                             | 3·20                             | 31·00     | 16·00     | 45·40             |

The Grevenmacher Luxemburg dolomite is used at the basic Bessemer Steelworks of Hayingen, Longwy, and Düdelingen, and after burning has the composition :—

|                    |                                  |              |      |
|--------------------|----------------------------------|--------------|------|
| SiO <sub>2</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO.         | MgO. |
| 2·0 to 3·0         | 3·0 to 6·0                       | 56·0 to 57·0 | 37·0 |

A dolomite suitable for use in the lining of basic open-hearth furnaces is found near Karánsebes, Örményes, Hungary. It has the composition shown by the following analysis, an analysis of the burnt material being also given : \*—

|                               | Raw.      | Burnt.    |
|-------------------------------|-----------|-----------|
|                               | Per Cent. | Per Cent. |
| Silica . . . . .              | 1·54      | 0·70      |
| Alumina . . . . .             | 1·28      | 0·22      |
| Ferric oxide . . . . .        |           | 2·58      |
| Lime . . . . .                | ...       | 57·75     |
| Magnesia . . . . .            | ...       | 37·82     |
| Carbonic anhydride . . . . .  | ...       | 0·93      |
| Calcium carbonate . . . . .   | 52·50     | ...       |
| Magnesium carbonate . . . . . | 44·10     | ...       |
| Totals . . . . .              | 99·42     | 100·00    |

**The Styrian Deposits of Magnesite.**—Professor Wedding † observes that magnesite deposits occur at the foot of the Semmering, and that they extend to the neighbourhood of Veitsch in Styria, where the deposit reaches its greatest development. The formation is Silurian, consisting of argillaceous shales, quartzite, dolomite, and limestone, which in turn rest upon gneiss. The magnesite, which is rarely pure, conforms with the strata. It is usually seamed with small stringers of limestone, dolomite, and quartz, with occasional segregations of dolomite crystals. Cobbing is therefore necessary. The picked magnesite is next calcined,

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 20.

† *Stahl und Eisen*, vol. xiii. pp. 279–286.



used for repairs in each heat. It is stated that a well-rammed magnesia hearth will often outlast three Dinas roofs. Again, the hearth may be built up of magnesia bricks, but these bricks must be of special shape to reduce the quantity of binding material or mortar to a minimum. This mortar consists of finely powdered slag from the furnace mixed with magnesia. It is not desirable to build in the material by itself, as the specifically lighter magnesia would rise up through the bath of metal. An inverted arch should be the arrangement adopted in all such constructions. “Milk” of dolomite is sometimes used instead of tar in binding the ground magnesia, but its use is not always successful.

**Magnesia Bricks.**—Dr. C. Bischof\* gives the following analyses of magnesite used in the manufacture of magnesia bricks :—

|                           | Styrian.     | Greek.                              |
|---------------------------|--------------|-------------------------------------|
|                           | Per Cent.    | Per Cent.                           |
| Magnesium carbonate . . . | 90·0 to 96·0 | 94·46                               |
| Calcium carbonate . . . . | 0·5 to 2·0   | 4·40                                |
| Ferrous carbonate . . . . | 3·0 to 6·0   | Fe <sub>2</sub> O <sub>3</sub> 0·08 |
| Silica . . . . .          | 0·0 to 1·0   | 0·52                                |
| Manganic oxide . . . . .  | 0·0 to 0·5   | H <sub>2</sub> O 0·54               |

Samples of these materials when burnt were found to contain :—

|                              | Styrian.  | Greek.         |
|------------------------------|-----------|----------------|
|                              | Per Cent. | Per Cent.      |
| Magnesia . . . . .           | 77·6      | 82·46 to 95·36 |
| Lime . . . . .               | 7·3       | 0·83 to 10·92  |
| Silica . . . . .             | 1·2       | 0·73 to 7·98   |
| Ferric oxide and alumina . . | 13·0      | 0·56 to 3·54   |

The Styrian magnesite was from the valley of the Veitsch, and the Greek from Mandondi, on the island of Eubœa. The Styrian magnesite is considered better suited for the manufacture of brick than is the Greek variety. It possesses in a marked degree the property of “sintering” or clotting together when heated to very high temperatures without actually fusing. In doing so its colour changes to a deep brown, or even to a blue black. This sintering action is apparently connected with the presence of iron and alumina. Various types of furnace, both kiln and reverberatory, are employed, lined with highly siliceous material, or with magnesia bricks themselves. The author describes a highly heated

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 27-30.



as possible. The burnt magnesite was crushed by rollers and sifted. To the fine powder a little magnesium chloride was added, and the mass was then pressed into bricks in a hydraulic press working with a pressure of 110 atmospheres, the pressure exerted upon each brick amounting to about 50 tons. The pressed bricks were carefully dried in the air, during which process they heat up slightly and become more dense and compact. After about a week they were burnt. The furnace used was the Mendesheim gas furnace, one of the circular or ring-shaped chamber ovens. The bed of this furnace was lined with magnesia bricks. A very high temperature was attained in this furnace, a mixture of felspar and clay being used for pyrometric purposes. The bricks produced had the composition—

|      |                    |                                  |                                  |      |
|------|--------------------|----------------------------------|----------------------------------|------|
| MgO. | SiO <sub>2</sub> . | Al <sub>2</sub> O <sub>3</sub> . | Fe <sub>2</sub> O <sub>3</sub> . | CaO. |
| 80·9 | 4·8                | 1·6                              | 6·8                              | 6·5  |

As to the relative cost of manufacture of these bricks when compared with that of ordinary fire-bricks, it is found that the magnesia bricks are much the more expensive of the two. The raw material is dearer, the necessary preliminary operations are more difficult, and the high temperature needed for burning the bricks cannot be attained without extra expense. A magnesia brick will only stand contact with clay up to a temperature of about 1600° C. If the temperature exceeds this, it will be found that a piece of magnesia brick placed upon a clay slab will melt down to a grey thin fluid mass which will pierce the clay slab on which it rested. If, instead of clay, pure alumina was used, then the magnesia stands somewhat better, though not to any very great extent. If, however, the burnt magnesia lump is placed on coke or gas-retort carbon, it may be heated almost to the melting-point of platinum without fusing, and some of this material from Veitsch in Styria has shown sharp edges even when raised above the melting-point of that metal. Pure magnesia stands this temperature readily, provided always that there is nothing else present with which, in its character of a base, it can enter into combination.

**Hungarian Chrome Iron Ore.**—W. Soltz\* publishes the following analysis of a chrome iron ore found in considerable quantity in the neighbourhood of Orsova, Hungary:—

|                                  |       |                    |                                  |      |       |
|----------------------------------|-------|--------------------|----------------------------------|------|-------|
| Cr <sub>2</sub> O <sub>3</sub> . | FeO.  | SiO <sub>2</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO. | MgO.  |
| 38·95                            | 17·13 | 8·00               | 17·50                            | 2·20 | 17·20 |

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 19.

He adds that it is remarkable that in open-hearths lined with chrome iron ore, scarcely any chromium passes into the resulting ingot metal.

**Standard Size for Fire-Bricks.**—At the general meeting of the Society of German Manufacturers of Refractory Products, held on March 1, 1893, it was decided to adopt 250 by 123 by 70 millimetres (9·84 by 4·84 by 2·78 inches) as the standard size for fire-bricks.\*

**A Regenerative Kiln.**—A regenerative kiln, designed by Mr. F. C. Roberts, is illustrated in the *Iron Age*.† The plant actually illustrated is not arranged for fire-brick manufacture, but it consists of three kilns operated by one set of regenerative chambers in which the air is pre-heated. The arrangement of the plant is described in detail. Taylor gas producers are employed, burning anthracite pea coal.

\* *Mittheilungen über Gegenstände des Artillerie- und Geniewesens*, 1893, p. 353.

† Vol. 1. p. 1219, two illustrations.

# FUEL.

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### I.—CALORIFIC VALUE.

**Calorific Value of Coal.**—C. von John and H. Baron von Fullon \* have made a series of assays of fuel by the Berthier method in the laboratory of the Austrian Geological Survey. Although the results obtained by this method are not of scientific value, they are, in the author's opinion, of practical use in indicating the quality of a coal when other data are not available. The following table gives the calorific power calculated from the elementary analysis of the fuel, and obtained experimentally by Berthier's method.

| No. | H <sub>2</sub> O. | Ash.      | C.        | H.        | N+O.      | S.        | Calories.   |             |
|-----|-------------------|-----------|-----------|-----------|-----------|-----------|-------------|-------------|
|     | Per Cent.         | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Per Cent. | Calculated. | Berthier's. |
| 1.  | 3.50              | 21.50     | 72.46     | 0.80      | 1.51      | 0.23      | 6069        | 6045        |
| 2.  | 22.35             | 5.15      | 59.11     | 4.23      | 8.24      | 0.92      | 5717        | 5269        |
| 3.  | 10.58             | 6.42      | 64.09     | 5.09      | 11.33     | 2.49      | 6352        | 5851        |
| 4.  | 8.70              | 2.76      | 67.01     | 4.29      | 17.24     | ...       | 6026        | 5669        |
| 5.  | 6.34              | 10.98     | 69.27     | 4.02      | 8.42      | 0.97      | 6522        | 6113        |
| 6.  | 7.54              | 10.08     | 67.12     | 4.83      | 10.51     | 0.92      | 6163        | 5892        |
| 7.  | 10.65             | 9.84      | 66.13     | 3.65      | 8.70      | 1.03      | 6046        | 5796        |
| 8.  | 20.40             | 3.95      | 52.06     | 4.12      | 18.03     | 1.44      | 4593        | 4171        |
| 9.  | 18.65             | 5.35      | 51.27     | 4.08      | 19.40     | 1.25      | 4463        | 4072        |
| 10. | 3.00              | 16.16     | 45.27     | 3.90      | 21.67     | ...       | 3811        | 3318        |
| 11. | 1.50              | 13.12     | 62.07     | 4.51      | 18.74     | ...       | 5711        | 5374        |
| 12. | 19.50             | 2.36      | 56.61     | 4.19      | 17.34     | ...       | 5035        | 4617        |
| 13. | 19.18             | 7.74      | 52.91     | 4.10      | 13.96     | 2.11      | 4918        | 4597        |
| 14. | 27.32             | 3.74      | 48.42     | 3.69      | 14.36     | 2.47      | 4353        | 4323        |
| 15. | 25.80             | 3.85      | 53.73     | 4.30      | 12.24     | 0.08      | 5104        | 4860        |
| 16. | 25.50             | 2.70      | 54.36     | 4.52      | 12.89     | 0.03      | 5204        | 5049        |
| 17. | 11.90             | 25.50     | 48.35     | 3.23      | 10.06     | 0.96      | 4635        | 4298        |
| 18. | 11.64             | 17.20     | 48.60     | 4.19      | 14.06     | 4.31      | 4626        | 3485        |
| 19. | 9.44              | 39.09     | 33.31     | 3.33      | 12.68     | 4.15      | 3006        | 2146        |
| 20. | 33.30             | 4.74      | 47.62     | 2.56      | 9.02      | 2.76      | 4000        | 3155        |
| 21. | 25.38             | 17.70     | 37.12     | 2.83      | 13.31     | 3.66      | 3158        | 2895        |
| 22. | 26.90             | 14.04     | 43.54     | 2.52      | 10.22     | 2.78      | 3703        | 2927        |
| 23. | 17.76             | 6.32      | 50.68     | 3.96      | 17.77     | 3.51      | 4534        | 4416        |
| 24. | 21.35             | 8.95      | 47.30     | 4.61      | 15.14     | 2.65      | 4515        | 3844        |

1. Anthracite from Orselia, near Genoa; 2. Trzebinia (lower carboniferous); 3. Temcsinek, Galicia (Schatzlar beds); 4. Buschtehrad; 5. Washed smalls from the same

\* *Jahrbuch der k.k. geologischen Reichsanstalt*, vol. xlii. p. 155.





gradually lessens, more and more carbonic oxide and less carbonic anhydride being formed, until at the temperature of  $995^{\circ}$  C., and at still higher temperatures, only carbonic oxide is formed and no carbonic anhydride. This explains the combustion of charcoal without flame at a temperature of  $700^{\circ}$ , while at  $1000^{\circ}$  a flame becomes visible.

**The Temperature of the Electric Arc.**—J. Violle \* has again determined the temperature of the electric arc. This he places at  $3500^{\circ}$  C., or that at which carbon volatilises. The quantity of heat which is required to bring one gramme of graphite to the point at which it volatilises is 1600 calories, and Weber and Dewar have shown that 300 calories are required to raise it from  $0^{\circ}$  to  $1000^{\circ}$  C. This the author employed as the basis for his determination, the most heated portion of the positive carbon being broken off, and allowed to fall into a calorimeter designed especially for the purpose.

H. Moissan † describes an electrical furnace in which by the use of a 50 h.p. engine, giving a current of 450 ampères and 70 volts, a temperature of about  $3000^{\circ}$  C. can be obtained. When using this furnace, it was found that at about  $2250^{\circ}$   $\text{Cr}_2\text{O}_3$  and  $\text{Fe}_3\text{O}_4$  melt rapidly; lime, strontia, and magnesia crystallise in a few minutes at  $2500^{\circ}$ , and the oxides of nickel, cobalt, manganese, and chromium are rapidly reduced by the carbon pole of the furnace at this temperature. As the temperature approached  $3000^{\circ}$  the oxide of uranium was reduced to the metallic form, 120 grammes of the metal being made in ten minutes. At this temperature, too, the lime of which the furnace was composed began to melt down rapidly.

The author states that using an electric furnace, pure alumina melts at  $2250^{\circ}$  and then crystallises. By the addition of small quantities of chromic oxide, small crystals of ruby resulted. Ferric oxide fuses rapidly, yielding partly fluid and in part crystallised magnetic oxide. Both ferric and chromic oxides yield fusible compounds with lime under these conditions, which crystallise well. The oxides of nickel and cobalt are readily fused; titanous anhydride yields black crystals of the lower oxide, which is rapidly volatilised, as also are both boric acid and alumina.

**Pyrometry.**—Mr. G. C. Farkell and Mr. H. G. Hamman ‡ discuss the determination of temperature by the change in the electrical resist-

\* *Comptes Rendus de l'Académie des Sciences*, vol. cxv. p. 1273.

† *Ibid.*, vol. cxv. pp. 1031-1034.

‡ *The Sibley Journal of Engineering*, vol. vii. pp. 53-57.



Using the Berthier method of ignition with lead oxide, a calorimetric effect of 5405 calories was obtained, the button of lead reduced by one gramme of the fuel being 23·102 grammes in weight. The ash of this lignite most unexpectedly showed the presence of large quantities of vanadium, the results showing as much as 38·22 per cent. of  $V_2O_5$ , 80 per cent. of which was present either as the oxide or as an alkali salt, being soluble in hot ammonia water. The ton of lignite contains  $4\frac{1}{2}$  lbs. of  $V_2O_5$ , and its ash forms perhaps the richest known ore of vanadium that occurs in any quantity.

**Coal at Bryncoch.**—A seam of coal six feet in thickness has been struck at a depth of 430 yards at the new pits of the Main Colliery Co. at Bryncoch, near Neath. These pits had been sixteen months in process of sinking, during which period more than 100 yards of very hard rock had been passed through.\*

**The Wigan Cannel-Coal.**—Mr. G. Caldwell † recently exhibited some fossil plant remains from the Wigan four-foot mine, and describes the cannel-coal seam found there. This seam practically occurs only under the township of Abram, where it reaches a thickness in places of six to eight feet, tapering off in all directions down to nothing. The top coal is generally about the same thickness of six to eight inches, and the bottom coal averages from  $2\frac{3}{4}$  to  $3\frac{1}{4}$  feet, but on its upper side partakes largely of the nature of cannel where that coal is the thickest.

**The Lanarkshire Coalfield.**—In a paper read before the Philosophical Society of Glasgow, Mr. R. T. Moore, ‡ describing the recent development of the Hamilton coalfield, observes that in 1845 the total quantity of coal raised in Scotland was estimated at 4,000,000 tons. In 1891 this had increased to 25,000,000 tons, of which 14,000,000 tons was from Lanarkshire. The output of the Hamilton field was 1,200,000 tons in 1856, and 7,500,000 tons in 1890. The upper group of Coal Measures in this field will be exhausted, the author thinks, in twenty-four years, and the whole of the coal in sixty years.

**Coal in the North of France and in the South of England.**—Professor M. Bertrand § has carefully studied the question of the cor-

\* *Mining Journal*, vol. lxiii. p. 129.

† *Transactions of the Manchester Geological Society*, vol. xxii. pp. 211-215.

‡ *Mining Journal*, vol. lxiii. p. 165.

§ *Annales des Mines*, 9th series, vol. iii. pp. 5-83 (with 2 plates.)







| Hygroscopic<br>Water. | Carbon. | Hydrogen. | Oxygen, Nitrogen,<br>and Sulphur. | Ash. | Total. |
|-----------------------|---------|-----------|-----------------------------------|------|--------|
| 3·77                  | 90·40   | 1·70      | 2·03                              | 2·10 | 100·00 |

or, without either ash or water, 96·05 per cent. of carbon, 1·80 per cent. of hydrogen, and 2·15 per cent. of oxygen, nitrogen, and sulphur taken together. When heated in a closed vessel, this anthracite gave 4·93 per cent. of volatile products, leaving a solid residue which weighed 95·07 per cent. of the weight of the fuel retorted. When similarly treated, two samples of the Skela anthracite gave respectively 4·10 and 7·14 per cent. of volatile products, with 95·90 and 92·86 per cent. of solid residue or "fixed carbon." Other details as to the extent or thickness of these beds are not given, and the fuel does not as yet appear to have been mined to any very important extent.

**The Sabero Coalfield.**—This Spanish coalfield has hitherto remained unworked, owing to the want of transport. Now, however, a railway has been constructed between La Robla and Valmaseda, and this passes through the Sabero district. M. D. L. Mallada,\* who has inspected this district, estimates that in a group of mines he examined there exists 32,538,450 tons of coal. This coal contains only a moderate percentage of ash, and yields from 80 to 84 per cent. of coke. It is stated to be of good quality.

**Coal in the Caucasus.**—According to R. Helmhacker,† in the northern flank of the Caucasus chain two distinct Carboniferous horizons are met with. On the Kuban River, the sandstone strata, in which the coal-seams occur, are upheaved by porphyry. On the right bank of the river the coal is being worked, mining operations dating back to the year 1846.

The bituminous shale of Jurassic age is also of economic importance. Near Gunib, a seam, varying in thickness from 2 feet to 6 yards, occurs. Although the shale contains too large a proportion of ash and of pyrites, it is used as fuel, some 1150 tons being raised annually.

The most important deposit of Liassic coal is at Tkvibul, thirty miles north-east of Kutais. The total thickness of coal is 50 feet. From the three mines working this deposit, some 1600 tons of coal is annually raised.

Lignite occurs on the Kury River. The lignite is of a black colour, has a conchoidal fracture, and contains 15 per cent. of ash. The author

\* *Revista Minera*, vol. xliv. p. 87.

† *Berg- und Hüttenmännische Zeitung*, vol. li. pp. 409-411.













In the United States, Ohio has furnished the largest number, if not all, of the cases reported. These are, without exception, composed of grey quartzite; they are well rounded, polished, and striated; and they have all been derived from a single coal-seam, the Middle Kittanning seam.

Mr. E. Orton \* now describes a new example of these boulders recently brought to light. It is of interest in that it is the first boulder that has been reported from the Sharon seam, the lowest member of the series. It is, too, not a metamorphic sandstone or quartzite, like those previously found, but is an excellent example of vein-quartz. It has not been worn by water or glacial action, but is angular as if freshly broken from the parent mass. No satisfactory explanation of these facts has yet been advanced.

**Coal from the Cumberland Field.**—The following is an analysis of coal from the George's Creek Mines of the Cumberland, United States, coalfield :—

| Carbon. | Hydrogen. | Oxygen. | Nitrogen. | Ash. | Moisture. | Volatile Sulphur. |
|---------|-----------|---------|-----------|------|-----------|-------------------|
| 79·40   | 5·11      | 3·80    | 1·25      | 9·24 | 0·58      | 0·62              |

The calorific value shown by a Thompson calorimeter was 13,452 heat units, and that by a working boiler test 10,817.†

**The Pennsylvania Coalfield.**—Mr. H. A. Wasmuth ‡ gives some notes on the stratification of the northern anthracite coalfield of Pennsylvania, describing the effect that the Susquehanna River had on the coal-seams in conjunction with faults in producing wash-outs and other troubles. To avoid flooding the mines, considerable pillars of coal have been left under the old river-bed, and coal has thus been wasted. A method of working is proposed to obviate the dangers due to flooding by robbing several of the pillars so as to produce a uniform break across the strata, and so to shut off the old river-bed by letting down the top clays.

Mr. B. S. Lyman § gives an account of an occurrence of coarse conglomerate above the Mammoth anthracite bed in Pennsylvania, with notes of other localities in which conglomerate is also found above the coal.

\* *American Journal of Science*, vol. xliv. pp. 62–63.

† *Iron Age*, vol. li. p. 297.

‡ *Journal of the Franklin Institute*, vol. cxxxiv. pp. 354–358, with plate.

§ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).









gaseous fuel, however, peat offers considerable advantages. The progress now being made in the effort to manufacture a first-class fuel from peat affords grounds for hoping that such fuel will shortly be available in Ontario. Before the problem of peat fuel is satisfactorily solved, however, many improvements in methods may yet be found necessary.

A report has recently been issued by the Foreign Office \* dealing with the results of inquiries on the manufacture of fuel and other products from peat. In Jutland peat moors extend over ninety square miles, but all methods of treatment have been found to be impracticable or impossible. At the present time a small amount is used in Denmark for local consumption. It is simply cut and dried, or pressed into blocks.

In the Brest and Cherbourg consular district there is no peat industry of any account. Some is cut near Marseilles and used at Lyons. Peat bogs are found around in the Bordeaux district, and 7000 tons are cut annually in the Charente district. Some peat fuel is used in Paris.

In Germany peat is used locally, but it does not pay as a rule to carry it more than twenty miles. No statistics are available, but it is estimated that 150,000 tons are burnt annually in the Grand Duchy of Oldenburg. The method of cutting and drying peat at Carolinenhurst is given. The peat is cut to a depth of 3 to 5 yards. The upper  $4\frac{1}{2}$  feet is used for litter and the remainder is cut into blocks, which are air-dried in pyramidal stacks. The German exports of peat in 1891 is given as 11,457 tons, and imports 13,073 tons.

In the Netherlands black turf is used in brick-kilns along several of the rivers. The peat is dug between the middle of March and the middle of June, and is water-borne after drying. In Holland turf is also used in the natural state, besides which it is carbonised in heaps or in ovens, but the product is very porous.

In Russia peat is found in forty-five provinces over an area of 67,000 square miles, and is extensively used in manufactures and also for locomotives.

In Sweden and Norway peat is largely used as domestic fuel, but has not come into much use for manufacturing purposes. Some ironworks use a small quantity mixed with other fuel. About 25,000 to 30,000 tons are used yearly for metallurgical purposes.

**Peat Ash.**—Ash from the Buchscheiden peat, analysed by Dr. E. Prziwoznik † in the laboratory of the Government Assay Office in Vienna, gave the following results :—

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\* *Foreign Office Report.*

† *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. p. 482.











**The Gases from Coke-Ovens.**—A. Hüssener \* gives the following analyses of gases passing to the scrubbers from Otto coke-ovens :—

| Description.                 | I.                   | II.                  |
|------------------------------|----------------------|----------------------|
|                              | Per Cent. by Volume. | Per Cent. by Volume. |
| Carbonic anhydride . . . . . | 0·90                 | 0·88                 |
| Hydrogen sulphide . . . . .  | 0·40                 | 0·43                 |
| Heavy hydrocarbons . . . . . | 2·33                 | 2·03                 |
| Oxygen . . . . .             | 0·44                 | 0·41                 |
| Carbonic oxide . . . . .     | 4·46                 | 4·61                 |
| Light hydrocarbons . . . . . | 27·36                | 24·71                |
| Hydrogen . . . . .           | 58·37                | 61·40                |
| Nitrogen . . . . .           | 5·74                 | 5·51                 |
| Totals . . . . .             | 100·00               | 99·98                |

With the specific gravity of air as a unit, the specific gravity of these gases was 0·355. Similar coal treated for illuminating gas in the ordinary way usually shows 2 per cent. by volume of carbonic anhydride and 8 per cent. of carbonic oxide.

**Recovery of By-Products from Coke-Ovens.**—In discussing the recovery of by-products from coke-ovens, Mr. C. Dreyfus † ascribes the fall of prices of benzene and anthracene to the larger production. The Hoffmann-Otto ovens, for instance, have increased in number from 40 in 1884 to 1205 in 1892 in Germany. One of these ovens cokes 6½ tons of coal in forty-eight hours. The following details, amongst others, are given by the author :—

| District.               | Coal Coked per Oven, Tons. | Yield per Cent. |       |                      | Saving in Coal per Day by Use of Gas, Tons per Oven. |
|-------------------------|----------------------------|-----------------|-------|----------------------|------------------------------------------------------|
|                         |                            | Coke.           | Tar.  | Sulphate of Ammonia. |                                                      |
| Ruhr . . . . .          | 1125                       | 75-77           | 2·3-3 | 1·1-1·2              | 0·35                                                 |
| Upper Silesia . . . . . | 1170                       | 65-70           | 4-5   | 1·0-1·15             | 0·44                                                 |
| Saar . . . . .          | 960                        | 68-72           | 4-3   | 0·8-0·9              | 0·35                                                 |

Details are also given of the performance of Semet-Solvay ovens.‡ It is now about three years since benzol was recovered directly from the gas, besides tar and ammonia. The process, devised by F. Brunk, is

\* *Stahl und Eisen*, vol. xii. p. 967.  
† *Journal of the Society of Chemical Industry*, vol. xi. pp. 879-881.  
‡ *Journal of the Iron and Steel Institute*, 1892, No. II., p. 373.





Upper seams are generally richer in oil and the lower ones in ammonia. Usually the shale is mined by long-wall methods when the seam is under 4 feet in thickness, and by pillar and stall methods in thicker seams. The material has to be blasted and is riddled through a 1-inch sieve, the smalls being left underground. As a general rule, the methods of working are similar to those used in coal-mines.

For the preparation of oil, the shale is passed through breakers, and then distilled in vertical retorts about 28 feet high and placed in benches of 80 back to back. Each retort holds some 30 cwts., 8 cwts. being charged at a time, and a similar amount being discharged below every six hours. The lower parts of the retorts are most intensely heated, and steam is passed in to aid the evolution of ammonia. The products are drawn off and passed through condensers. From 1 to 3 cwts. of coal are used per ton of shale as fuel to heat the retorts. At the present time the industry is rather in a decadent state, owing to competition from other sources.

**Petroleum in France.**—A. Charlon \* reviews the various occurrences of oil and the explorations made for it in France. Oil has been found in the bitumen mines at Pechelbronn in Alsace. At Gabian, Herault, in the Tertiary series, several wells have been sunk, and a small quantity of oil and a good deal of gas have been obtained. Not far from Grenoble, gas escapes from fissures in the soil, and a well has been sunk over 200 yards deep, but without finding oil. In several of the bitumen-yielding districts some prospecting has been done. At Pont Battu, near Riom, a well sunk to a depth of 298 yards passed through gas-bearing layers at about 87, 130, and 214 yards. At this latter depth salt water charged with oil was found, followed by bitumen and heavy viscous oil. At the lowest depth reached, a small amount of oil was also found, but not in payable quantity.

P. Dubreuil and J. de Clercy † describe the discovery of petroleum-bearing beds in the Limagne d'Auvergne. The plain situated at the feet of the Monts-Dome being thought by M. de Clercy to be favourable to the occurrence of petroleum, he caused borings to be made in several places. The first of these reached a depth of 720 feet, but without result, but another, which is now down to the depth of 900 feet at the other end of the field, at Pont-Battu, in the neighbourhood of Riom, has shown the existence of beds impregnated with hydro-carbon gases

\* *La Nature*, vol. xl. pp. 81-82.

† *Génie Civil*, vol. xxii. p. 103, 2 illustrations.



beds are now known to exist. Though not very rich, the oil is of a very low specific gravity, 0·841 to 0·858. By deeper boring it is probable that richer deposits of oil will be found; hitherto the wells sunk have not exceeded a depth of about 80 yards. At Naphta-Tschala, to the south of Baku, considerable deposits of oil occur. According to N. Kwiatkowski, the oil has a specific gravity of 0·918, and yields as little as 9 per cent. of petroleum of the specific gravity 0·829. Here, too, deeper wells may yield an oil of better quality.

**Occurrence of Petroleum in Gaspé, Quebec.**—Mr. H. P. Brumell\* notes the occurrence of oil in Gaspé county, Quebec, where desultory work has been carried on for many years, the result being the establishment of the fact that deep-seated oil of superior quality exists, though in what quantity future development alone can tell. The oil is obtained from limestone of Lower Devonian or Upper Silurian age.

**Petroleum Wells in the United States.**—The number of petroleum wells in the United States amounts to about 46,000. Their daily yield of oil approximates to 130,000 barrels.†

**Petroleum of the Crow's Neck Pass, Rocky Mountains.**—In a paper read at the fifth annual meeting of the Geological Society of America at Ottawa, Dr. A. R. C. Selwyn referred to the enormous quantities of coal which have lately been found in the vicinity of Michel Creek, near the Crow's Neck Pass. After reviewing his work in this district, he went on to describe the petroleum of the South Kootenai Pass, in which two distinct occurrences were noted. One of these is on Cameron Falls Brook, where a heavy dark-brown oil was found floating on the surface of the stream; the other is on Akamina Brook, in British Columbia, where the oil was found in a similar manner, but of much lighter colour and gravity. Both these oils are from Cambrian rocks.

**Californian Petroleum.**—The crude petroleum from Pico Cañon, Los Angeles county, is viscid and of a dark-green colour. Its specific gravity is 0·8414. A preliminary examination by Mr. F. Lengfield and Mr. E. O'Neill‡ shows that this oil contains parafins, naphthenes, and homologues of benzine. It is probably intermediate in character between Pennsylvanian and Russian petroleum.

\* *The American Geologist*, vol. xi. p. 131.

† *Revista Minera, Metalurgica y de Ingenieria*, vol. xliv. p. 79.

‡ *American Chemical Journal*, vol. xv. pp. 19-21.



valley of Mantaro, near Sorao and Huari, are of great geological interest, and may eventually prove of economic importance. The chief exploratory workings have been made at the latter locality. The veins worked course from north-east to south-west, and have a dip of  $85^{\circ}$  to the north-west. They traverse horizontal beds of limestone of a yellowish grey colour. The vein is 5 to 6 feet in width. Both walls of the vein are covered with a thin hard layer of yellow clay, which in many places exhibits slickenside faces. The vein stuff fills the entire width of the fissure; and, when freshly brought from the mine, it has a shining appearance and resembles splint coal. On exposure to the atmosphere it soon loses its lustre and crumbles away.

The workings at present are on a small scale. Only four men are employed, the daily output being 5 to 6 tons.

**Sumatra Petroleum.**—Some tests, made by Mr. Leyden, on the Langkat oil of Sumatra, as compared with Russian and American oils, have recently been published.\* The specific gravity of this oil at  $15^{\circ}$  C. is 0.799. It is colourless, and it has a good illuminating power. By distillation, 79.6 per cent. is obtained between  $150^{\circ}$  and  $270^{\circ}$ .

## VI.—NATURAL GAS.

**Origin of Natural Gas.**—The various theories of the origin of oil and natural gas are shortly discussed by Mr. J. Young.† The theory of origin by the interaction of water containing carbonic acid and fused metals is chemically perfect, but is not generally accepted by geologists, and the facts point rather to one of the theories depending on distillation or on primary decomposition as being the true explanation. Simple or fractional distillation explains many of the facts, but it has been shown that in some cases at least the rocks from which the oil might have been derived show no signs of metamorphism. Primary decomposition, on the other hand, can be observed at the present day in Trinidad, where recent beds of shale yield petroleum and asphalt. The author, however, considers that both of these theories merge into one another, and that the difference of distillation and decomposition is merely one of degree.

\* *Board of Trade Journal*, vol. xiv. pp. 349–350.

† Lecture before the Western University of Pennsylvania, through the *Colliery Guardian*, vol. lxxv. p. 634.









the total quantity produced, 93 per cent. was in the gas, and only 7 per cent. in the tar in the case the author quotes. Still, the gas was not saturated with benzene and toluol. Indeed, it only contained 4 per cent. of the quantity which would be required to effect the saturation; consequently, any cooling influence to which the gas may be subjected is not likely to seriously affect the percentage of benzene which it contains; and the author considers that, in order to avoid the difficulties which so often result from the deposition of naphthalene in the pipes, the gas should be thoroughly cooled in the first instance.

**The Manufacture of Gas.**—A. Henin \* discusses the production of heating gas and ammonia from coal in the producer, and points out that the main conditions of the formation of ammonia are also favourable for the production of a good heating gas. High temperature, however, is not compatible with a large excess of steam, unless the latter is highly super-heated, or unless air is also admitted. The author finds that with the steam moderately super-heated and evenly distributed, a limited supply of air will maintain the temperature sufficient to allow the admittance of 1 to  $1\frac{3}{4}$  lb. of high-pressure steam to the pound of coal. Under these circumstances 50 to 60 per cent. of the nitrogen in the coal is transformed into ammonia, and the composition of the gas is as follows :—

| CO <sub>2</sub> . | O.   | CO    | Methane, &c. | H.    | N.    | Total. |
|-------------------|------|-------|--------------|-------|-------|--------|
| 10·50             | 1·00 | 20·00 | 4·50         | 38·00 | 26·00 | 100·00 |

When the gas is quickly drawn off, the reactions seem to be facilitated by the partial vacuum, the ammonia is not dissociated, and the temperature is easily maintained. Each ton of coal will yield from 70 to 80 lbs. of ammonium sulphate, 130,000 to 150,000 cubic feet of gas, and 15 to 20 gallons of tar. To remove the ammonia without unduly moistening the gas, it should be well cooled before it is passed through the scrubbers.

Some experiments have been carried out at the Mitchell Main Colliery, near Burnsley, on the utilisation of shale for the manufacture of water-gas. The trials appear to have been successful.†

\* *Chemical Trade Journal*, vol. xi. pp. 147-148.

† *Colliery Guardian*, vol. lxxv. p. 715.







Another specification \* gives the dimensions of a wrought iron head-gear recently constructed. It is 46 feet high to the pulley centres, the main legs are  $44\frac{3}{4}$  feet long, the backstays  $71\frac{1}{2}$  feet. It is built up of lattice-work and angle iron, the dimensions being fully given.

**Self-Acting Inclines.**—The several methods of working self-acting inclines on steeply-inclined seams by means of a counterbalance and a carriage on which the tub is placed, are discussed by Messrs. D. M. D. Stuart and J. Sparkes,† and a description is given of a special arrangement for this purpose which has been at work for the past twelve months in the Bristol coalfield. The counterbalance has been used on a line of rails at one side of the main track, but then the coal on one side of the road is not easily worked. In several instances the counterbalance track is placed between the lines of rails on which the carriage runs. This necessitates that the carriage should be built high enough to let the counterbalance pass underneath, or else that the outer rails should be raised or the inner ones lowered, or both, either over the whole track or at the passing places only. In the latter case, the change of gradient is more or less abrupt, and in either case there is difficulty in laying the rails with transverse sleepers. In the particular form of carriage described by the authors, there are four equal-sized wheels, and the tub is carried by a horizontal platform, which is supported on the axles by a built-up triangular iron framework strengthened by angle pieces at the corners. The framework is so designed that the angles can be adjusted to keep the platform level. Further, the axles are cranked to allow room for the counterbalance to pass underneath. This counterbalance consists of a simple frame on wheels, with a number of weights in the form of iron bars, that can readily be removed or replaced to adjust the weight.

Mr. S. Alsop‡ gives a description of a self-acting endless chain used for lowering the tubs from one seam to the pit-bottom, 50 feet below. A stone drift with a gradient of 1 in 3 is used, and the chain is made of riveted links, two 6 inches long and then one of 12 inches, working round a hexagonal drum. Pegs or sprockle links are put in every 42 feet to hold the tubs. The chain runs at about  $1\frac{1}{2}$  mile per hour, lowering the full tubs and lifting the empty ones. It is 340 feet long,

\* *The Practical Engineer*, vol. vii. pp. 170–172.

† Paper read before the National Association of Colliery Managers, March 28, 1893, *Colliery Manager*, vol. ix. pp. 64–65. Patent No. 675, 1892.

‡ *Transactions of the National Association of Colliery Managers*, January 14; *Colliery Manager*, vol. ix. p. 6.









1150 revolutions per minute, and drives the chain at a rate of  $2\frac{1}{4}$  miles per hour. It is supplied with current from a dynamo giving 20 amperes at 410 volts when running at 880 revolutions. The efficiency is 85 per cent., rising to 88·8 per cent. with a maximum load, or 65·4 and 68 per cent. respectively of the work done by the engine driving the dynamo. The cost of the engine, dynamo, and house was £359, of the electric plant underground also £359, and of the haulage plant, including the chain, £237. The costs by the two systems may be tabulated as follows :—

| Description.                                 | Cost per Truck. |        | Cost per Annual Output of 800 Trucks Daily. |        |
|----------------------------------------------|-----------------|--------|---------------------------------------------|--------|
|                                              | Locomotive.     | Chain. | Locomotive.                                 | Chain. |
|                                              | d.              | d.     | £                                           | £      |
| Steam . . . . .                              | 0·056           | 0·062  | 54                                          | 38     |
| Labour . . . . .                             | 0·141           | 0·312  | 135                                         | 187    |
| Lubricant and repairs . . . . .              | 0·038           | 0·075  | 36                                          | 45     |
| Interest and depreciation of plant . . . . . | 0·112           | 0·175  | 108                                         | 107    |
| Totals . . . . .                             | 0·347           | 0·624  | 333                                         | 377    |

The choice between these two methods is determined by local conditions, but probably the locomotive is most suited for small and medium outputs and distances, and they may often replace horses with advantage.

An illustration is given \* of an electric locomotive for a track of 30-inch gauge. It is  $9\frac{1}{2}$  feet long, 3 feet wide, and  $4\frac{1}{2}$  feet high. The wheels are  $2\frac{1}{3}$  feet in diameter, and the wheel base is  $3\frac{1}{3}$  feet long. Each axle is driven by its own motor. The trolley pole can be placed on either side, and is insulated. Similar locomotives to these are at work, and a few particulars have been given. A 48-horse power locomotive on an incline of  $2\frac{1}{2}$  per cent. in favour of the load, and about a mile long, delivers 500 trucks from four working openings. A truck fitted with two 6-horse power motors takes about 200 trucks per day from the miners, an average distance of 2000 feet, and forms them into trains.

An illustration is given † of a mining locomotive, designed to meet the demand for a small and substantial machine. It has two motors, and is so arranged that it can easily be taken to pieces. For gauges narrower than three feet, four-pole motors are used.

\* *Engineering News*, vol. xxix. pp. 60, 117.  
† *Engineering and Mining Journal*, vol. liv. p. 583.











character. Hitherto this explosive has been but little known in Austria. The explosive experimented with was made in Belgium. Favier powder No. 1 consists of 88 per cent. of ammonium nitrate and 12 per cent. of dinitronaphthalene packed into white cartridges. The anti-fire-damp favierite No. 2 consists of 90 per cent. of the No. 1 powder and 10 per cent. of ammonium chloride in red cartridges. Both these powders, but especially the latter, proved very safe in the presence both of fire-damp and of coal-dust. There are two other kinds which are not intended for use in the presence of fire-damp. These are the blue cartridges, containing a mixture consisting of 92 per cent. ammonium nitrate and 8 per cent. dinitronaphthalene; and Favier powder No. 4, composed of 95.5 per cent. ammonium nitrate and 4.5 per cent. of the dinitronaphthalene. Only the two first of these were held to be of importance in the experiments, and the author describing them observes that the Favier cartridge can be safely subjected to all imaginable requirements; requirements, indeed, which can never occur in practice. The explosive does not freeze, and the only important objection which the author makes to it is that it requires a very strong detonator to effect its explosion. The explosive experiments are described in detail. The explosive No. 2 proved perfectly safe in the presence of the most dangerous mixtures of coal-dust and fire-damp; and with the explosive No. 1, out of the thirty-one experiments in which coal-dust was used alone, a partial ignition of the dust was observed in but a single instance, without any pronounced explosion; and in fourteen experiments with mixtures of fire-damp and coal-dust, not a single explosion took place; No. 3 explosive, on the other hand, produced, even with small charges, coal-dust explosions even when no fire-damp was present, and its use affords, therefore, no security. Compressed black powder, too, and No. 1 meganite always produced, even with small charges, explosions when present with Rossitz dust. The anti-firedamp favierite was found to be much safer than the other explosive of a similar name, grisoutite. This the author shows by a comparison of the results of numerous experiments made with the two explosives.

**New Explosives.**—A. Berg\* and Cari-Mautrand observe that mixtures of hypophosphites with chlorates form explosives, the use of which would appear practicable. One part of barium hypophosphite mixed with one part of potassium chlorate, both dried in the first instance and powdered very fine, gives a compound that, when ignited in the air, burns

\* *Bulletin de la Société Chimique*, 3rd Ser., vol. ix. p. 94.





appended dealing with charging, firing, faults, connecting, and general hints. Missfires with the high-tension system are often due to deterioration of the exploders, but this can be remedied by re-magnetising the magnets.

For extracting the tamping from a bore-hole after a missfire, it has been proposed by F. Kuhn to use an augur made of brass. In case of powder, the charge can be withdrawn if it is wetted; or if dynamite is used, a fresh charge is inserted a little way above the old one.\*

**Coal-Cutting Machinery.**—According to the seventeenth annual report of the Chief Inspector of Mines for Ohio, Mr. R. M. Haseltine, only one mine has lately adopted coal-cutting machinery, while five mines have discontinued their use. Of these, three used electricity and two compressed air as motive power. Mining machinery is now used in 21 mines. Of these, 13 use compressed air, 6 electricity, and 2 use both as motive power; 1,654,081 tons, or a gain of 505,632 tons over the preceding year, was produced by these means, which gave employment to 900 hands. There are 114 machines in use, of which 25 are electric and 89 are driven by compressed air. Electric haulage is employed in two mines.

In a paper on electricity applied to the mining of bituminous coal, Mr. E. A. Sperry † describes the pick machine devised by himself. The special feature in this machine is the connection between the percussive part and the rotary driving gear, by which the tool in its forward blow is independent of the driving gear, but is reconnected immediately the blow is delivered. The effect of recoil is thus minimised, and the machine may be made much lighter. The tool is retracted against the spring that delivers the blow by means of a connecting rod and crank. This crank is connected by a spring to an arm, which is loose on the driving-wheel, and is connected to it by a pawl, which immediately falls into gear and transmits motion as soon as the return stroke commences, but rides loose on the forward stroke of the tool when the latter has a greater speed than the driving-wheel. The machine is carried on a two-wheeled truck. The tool has a stroke of  $6\frac{1}{2}$  to  $7\frac{1}{2}$  inches, and weighs from 100 to 150 lbs. The current required is about 10 ampères at 220 volts. A very large amount of work has been successfully performed with these machines. The author also describes an electric

\* *Revue Universelle des Mines*, vol. xxi. pp. 334-335.

† *Transactions of the American Institute of Electrical Engineers*, vol. ix. pp. 375-406, with illustrations. *Journal of the Illinois Mining Institute*, vol. i. pp. 47-82, with illustrations.



opening out and working the rearer coals of North Staffordshire are described by Mr. E. Craig.\* These seams include those lying at angles between  $45^{\circ}$  and vertical, and are very numerous. They vary in thickness from 14 down to 4 feet, and the coal, the roof, and the floor vary through all degrees from good to bad. Seams at a less angle than  $45^{\circ}$  are not regarded as rearers at the present time, and are worked by ordinary methods. Rearers are opened out on the pillar and stall system. The pillars are exhausted from the rise downwards in breadths of 120 yards. A breadth is worked from vertical shafts through stone drifts from which levels are driven in the seam at the bottom of the breadth. Cage-dips are driven up from the level to within 10 yards of the top, and headings are put out on each side for a distance of 100 yards. The cage-dip, down which the coal is lowered, is laid with two lines of rails, and forms a self-acting incline, with a dummy or counterbalance on the inner and narrower line to haul up the empty cage and truck. The pillars are worked from the far end back to the cage-dip by means of shoulders from the bottom end. In the worked-out space the gob is formed, and on working out the next lower pillar, the gob is allowed to slide down to form a support for working on. The top workings are kept 12 to 15 yards in advance of the pillar below, and one dip will give about 120 tons per day.

**Long-Wall in North Staffordshire.**—The long-wall method of working in North Staffordshire, applied to seams varying in thickness from  $2\frac{3}{4}$  to 8 feet, and in dip from  $14^{\circ}$  to  $20^{\circ}$ , with roofs of hard and soft “metal,” is described by Mr. E. B. Wain.† This method has been carried on for some nine years at the Whitfield Colliery in five seams with unqualified success, both as regards safety and economy. The chief difficulties found were, first, the tendency of the roof to dip and sink away from the face, thus taking the working weight from the coal; and, second, the disturbance of the packs, &c., on the higher side of the level gateways, caused by the dipping of the roof. These difficulties are, however, overcome by paying careful attention to the packing and timbering and to the regular advance of the face. Special care is taken in building the first packs, and thus the opening-out stall is carried forward with a working face nearly in the line of full dip. In the thinner seams, ripping from the roof supplies material for the walls, which are kept in advance, and chocks are put in on the higher side of the road.

\* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 48-52, with plate.

† *Ibid.*, pp. 24-35, with two plates.

















conditions are quoted from several authorities to show that the Capell fan gives the greater efficiency. Amongst other things, two points are brought out: first, that fans passing different volumes of air from the same mine may show different water-gauge; and, second, that different makes of fan affect the gauge at varying distances in diverse manners, throwing back the gauge to a greater or less distance. This paper was keenly discussed, considerable doubt being thrown on the value of the experiments adduced and on the points above mentioned.

Some illustrations and description of experiments with Bumsted and Chandler's fan and engines have been given.\* At the Cossall Colliery, near Nottingham, one of these fans is driven by a pair of compound single-acting engines, one on each side of the fan. The diameters of the low and high pressure engines are 24 and 16 inches respectively, with a stroke of 16 inches. The cylinders are placed tandem, and have piston valves. The cranks run in an oil bath. At 220 revolutions with 125 lbs. boiler pressure and cut off at half stroke in the high-pressure cylinder, the engines indicate 320 horse-power. The fan is 15 feet in diameter and 6½ feet wide. A number of tests are given, of which the following are selections:—

| Revolutions. | Water Gauge<br>in Fan Drift. | Volume of Air. | Horse-power<br>in Air. | Indicated<br>Horse-power<br>of Engines. | Efficiency. |
|--------------|------------------------------|----------------|------------------------|-----------------------------------------|-------------|
| 150          | 2·8                          | 171,904        | 75·9                   | 106·48                                  | 71·28       |
| 151          | 3·1                          | 173,000        | 84·5                   | 117·17                                  | 72·1        |
| 204          | 5·2                          | 208,102        | 170·6                  | 260·25                                  | 65·5        |
| 205          | 4·75                         | 246,078        | 184·3                  | 261·40                                  | 70·5        |
| 204          | 5·5                          | 214,934        | 186·4                  | 263·50                                  | 70·74       |
| 200          | 4·5                          | 232,696        | 165·1                  | 230·00                                  | 71·5        |

In some of these experiments external air was admitted at the top of the upcast, as it was impossible to pass the guaranteed 250,000 cubic feet per minute for the fan through the mine at the stipulated water gauge. When the fan drift was entirely closed the water gauge was as follows:—

|                  |      |      |      |      |      |      |      |
|------------------|------|------|------|------|------|------|------|
| Revolutions . .  | 150  | 155  | 180  | 140  | 160  | 164  | 186  |
| Blade, top speed | 7068 | 7304 | 8482 | 6597 | 7539 | 7728 | 8764 |
| Water gauge .    | 4·1  | 4·4  | 6·0  | 3·5  | 4·6  | 5·0  | 6·4  |

Some results of further tests and other particulars of these fans have also been given by Mr. N. Chandler.†

\* *The Engineer*, vol. lxxv. p. 61.  
† *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 161-171.



recently-devised forms. It consists of five principal parts, a strong case into which the other parts are pushed upwards, an outer gauze and shield, an inner tube and separator, a glass with brass end rings. The oil reservoir is placed below these parts, which are kept in place by a bottom plate and lead rivet. A spring cushion is provided under the bottom plate to save the lamp from shock when set down. The wire-gauze is placed outside the shield. The objects and advantages of this lamp are described by Mr. W. E. Teale.\*

Mr. J. T. Bennett† describes the origin of the safety-lamp and several of the more recent forms. Attention is also drawn to the Piston safety-lamp.

Mr. A. Dick‡ states that the Davy lamp is still the favourite lamp in the United States for testing for gas. The Ashworth Hepplewhite Gray combination is mentioned as a good combined testing and illuminating lamp. A similar form, called the Nelson lamp, has been made in Pennsylvania. The Richards lamp, another gas-testing lamp, is a modified Clanny.

H. Kämmerer§ and T. Oppler have tested a number of different types of safety-lamps. Mixtures were made of different volumes of air with the vapours of a number of the more volatile combustible organic compounds, such as ether, alcohol, and benzene, as well as carbon bisulphide and hydrogen. One of the lamps examined could in no way claim the name of a safety-lamp, but, this one excepted, all the other lamps gave results with all the mixtures of vapours examined, except those of carbon bisulphide with air, which are embodied under the following heads :—(1.) If only a few per cent. of the gas is present, the flame is slightly lengthened, and it was observed in this connection that the flame of benzene lamps is far more sensitive than that of oil lamps. (2.) If larger quantities of gas are present, the elongation of the flame becomes still more marked; it becomes unsteady and rises above the wire-gauze to the cover of the wire cage; the flame, when it has been lengthened to this extent, shows a curved shape, is of a reddish hue in its upper portion, and begins to smoke. (3.) If the respective volumes of air and gas are such that the oxygen present only just suffices for the complete combustion of the gas—when, that is, the explosive power of

\* *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 172-176, with plate; *Transactions of the Mining Institute of Scotland*, vol. xiv. pp. 115-118, with plate.

† *Proceedings of the National Association of Colliery Managers*, vol. iv. pp. 356-362.

‡ *The Colliery Engineer*, Scranton, vol. xiii. p. 161.

§ *Journal für Gasbeleuchtung*, vol. xxxvi. p. 101.



Mr. H. White \* describes the Coal-miners' electric lamp. A single-fluid primary battery is used with non-corrodible platinum connections. The plates are of zinc. A three-cell lamp weighs 4 lbs. 2 oz., and a four-cell lamp weighs 5 lbs. 6 oz. The consumption of zinc in these two lamps is given as  $\frac{3}{4}$  and 1 oz. respectively for ten hours. The incandescent lamp is mounted with a glass shield, breakage of which puts out the light.

Mr. J. P. Rees † describes the Miners' electric lamp. The lamp bulb is protected by an outer glass casing, and air under pressure is forced between the two glasses. The pressure of this air causes the completion of the circuit, so that if the outer glass be broken the lamp is extinguished. It burns for 10 hours, gives a good light, weighs  $5\frac{1}{2}$  lbs., costs 25s. originally, and a shilling per week for maintenance. The current is supplied by a primary battery.

Some particulars are given of the Bristol electric lamp by Mr. T. Raaschow.‡ This is an accumulator lamp with three cells, and is said to be the lightest electric lamp made, a lamp giving  $1\frac{1}{2}$  candle-power for seven hours, weighing 27 oz. Estimates for the cost of installation and maintenance of these lamps are given.

**The Detection of Firedamp.**—In discussing the detection and estimation of small proportions of firedamp, petroleum vapour, and other inflammable gas or vapour in the air, Professor F. Clowes§ gives the criterion of an apparatus as to its convenience, its capability as an illuminator, its safety, and its accuracy and range. The first three have been fairly worked out, but the latter seemed to be worthy of further investigation. Most of the apparatus that have been devised for measuring firedamp depend on three different principles—on the increase of brightness of a heated platinum wire, on the decrease of pressure caused by burning the gas, or on the production of a cap over a flame. Liveing's apparatus is an example of the first type, and some experiments made by Mr. J. Grundy in the author's test chamber are given to show its accuracy. Hydrogen flames have been proposed, and also alcohol flames, to replace the ordinary safety-lamp, and the author has devised a means of combining the hydrogen burner with a safety-lamp. A large number of

\* *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 151-153, with plate.

† *Proceedings of the South Wales Institute of Engineers*, vol. xviii. pp. 167-168.

‡ *Ibid.*, pp. 36-47.

§ *Journal of the Society of Arts*, vol. xli. pp. 307-323; Patent No. 6051 of 1892; *Transactions of the Federated Institution of Mining Engineers*, vol. iv. pp. 441-459; *Journal of the Society of Chemical Industry*, vol. xii. pp. 326-327.

















above the true bottom. In the later machines the bottom is made of oak strips 30 inches long by  $4\frac{1}{2}$  inches in width. A specially formed curve is given to both bottoms. The table is supported from above by hangers, and has an endways movement of 3 to 6 inches, being retracted by cams and levers, and allowed to fall back against a bumping-block. Water is supplied between the bottoms and by sprays. Coal is discharged continuously at the tail end and dirt at the head end. The author finds that each table will wash 40 to 45 tons of coal daily, with the expenditure of  $\frac{1}{2}$  horse-power and 300 gallons of water per ton, at a cost of 1 to 1.5 penny per ton. Most of the coal washed was slack which would pass a  $\frac{3}{4}$ -inch screen. The dirt in the unwashed coal averaged 12.71 per cent., and in the washed coal 2.73 per cent. The coal passing over the head with the dirt was 1.64 per cent. The sulphur was reduced from 4.20 to 3.18, and the ash from 10.73 to 8.56 per cent. The coals washed were Nos. 9 and 11 of the Kentucky series.

**Washing Coal in Tennessee.**—Mr. G. W. Whyte\* gives an account of some experiments on the washing of coal from the Nelson Mine, Tennessee. This coal averages 14 per cent. of ash, but by curtailing the output of the mine by 24 per cent. the ash could be reduced to 9.45 per cent., or 15.75 per cent. in the coke. Fifty tons of the run of the mine was treated. The coal was screened, the larger lumps over  $1\frac{1}{2}$  inch hand-picked on belts and crushed, and then the whole was screened into four sizes. The three larger sizes were washed on bashes at 72 strokes per minute, then re-crushed, and treated like the smaller size on bashes running at 140 strokes. The results are given, and show that with this coal there was a loss of 27.30 per cent. of coal, and a coke with about 14 per cent. of ash was produced.

**Loading Coal.**—Mr. M. Walton Brown† describes the coal-loading wharf at Barsée, in connection with the Bethune Collieries, Pas de Calais. There are two tipplers, each capable of dealing with a waggon holding ten tons. They work by gravity, but are controlled by a brake and a hydraulic regulator. The coal is received by a wide shoot, which leads it to an articulated pipe by which it can be directed into the hold. A chain-hauling gear is used to move the boats. At the Lens Collieries the waggons are tipped sideways by the aid of a small crane attached to a locomotive.

\* *Engineering and Mining Journal*, vol. lv. p. 80.

† *Transactions of the Federated Institution of Mining Engineers*, vol. iii. pp. 1019-1021, with plate, p. 1026.





# PRODUCTION OF PIG IRON.

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### I.—BLAST-FURNACE PRACTICE.

**Relining a Blast-Furnace.**—In relining a blast-furnace at Youngstown, Pennsylvania, Mr. T. G. Davis\* abandoned the blowing-out method. That which he employed consisted in shutting off the blast and then drowning out the furnace with water, the stock being afterwards shovelled out. He has also abandoned the “sweep” centre pole used by furnace-builders, using instead cords suspended from the top of the well to the top of the boshes, placed 3 or 4 feet apart, and serving as a sufficient guide for the bricklayers. The scaffold is thus kept free from all obstructions excepting the stock brick, and a larger number of men can be simultaneously employed.

The furnace to be relined went out of blast on September 6, 1892, at 5.30 p.m., and the work of drowning it out was immediately commenced. It had been shovelled out and made ready for the bricklayers on September 13. Further operations were delayed until October 3, but upon that date the bricklayers commenced work at 10.30 a.m., and completed the relining by 9 a.m. on October 8. The furnace was ready to light on October 13, but owing to delays did not actually go into blast until the morning of October 16. The first cast of iron was obtained on the following morning, and during the second day thirty-five tons were made. The average daily out-turn of this furnace is 115 tons. It is furnished with two pipe-stoves.

\* *Iron Age*, vol. 1. p. 792.











































**Austrian Pig Iron.**—Dr. E. Przywoznik \* has published the results of a series of analyses of Austrian pig iron. Amongst these are the following :—

| Description.    | 1.        | 2.        | 3.        | 4.        |
|-----------------|-----------|-----------|-----------|-----------|
|                 | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Combined carbon | 3·41      | 3·42      | 4·49      | 4·74      |
| Silicon         | 0·28      | 0·16      | 0·28      | 0·83      |
| Phosphorus      | 0·07      | 0·09      | 0·73      | 0·14      |
| Sulphur         | 0·03      | 0·03      | 0·01      | 0·01      |
| Manganese       | 1·10      | 0·86      | 12·91     | 13·10     |
| Cobalt          | trace     | trace     | trace     | ...       |
| Copper          | trace     | trace     | trace     | 0·11      |
| Iron            | 95·11     | 95·44     | 92·23     | 81·07     |

White pig iron (1) from the Austrian Alpine Company's Works ; (2) from Eisenerz ; (3) spiegeleisen from Eisenerz, and (4) from Witkowitz.

| Description.    | 5.        | 6.        | 7.        | 8.        |
|-----------------|-----------|-----------|-----------|-----------|
|                 | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Combined carbon | 0·850     | 0·540     | 0·310     | 2·324     |
| Graphite        | 3·160     | 2·700     | 2·950     | 0·221     |
| Silicon         | 1·229     | 2·373     | 1·540     | 0·094     |
| Phosphorus      | 0·093     | 0·057     | 0·165     | 0·089     |
| Sulphur         | 0·018     | 0·022     | 0·025     | 0·090     |
| Manganese       | 3·099     | 3·520     | 3·856     | 1·497     |
| Copper          | ...       | 0·025     | 0·003     | trace     |
| Iron            | 91·551    | 90·763    | 91·151    | 95·685    |

Grey pig iron (5) from Vordernberg ; (6) from Mariazell ; (7) from Schwechat ; (8) from Hieflau.

**Analyses of Basic Bessemer Pig Iron.**—The following are analyses showing the average composition of the basic pig iron used at the works named : †—

| Works.  | C.        | Si.       | Mn.        | P.          | S.        |
|---------|-----------|-----------|------------|-------------|-----------|
|         | Per Cent. | Per Cent. | Per Cent.  | Per Cent.   | Per Cent. |
| Longwy  | ...       | 0·35      | 1·80       | 2·0 to 2·25 | 0·05      |
| Angleur | ...       | 1·00      | 1·50       | 2·00        | 0·05      |
| Hörde.  | 3·60      | 0·58      | 1·37       | 2·75        | 0·08      |
| Phoenix | 2·80      | 0·20      | 1·8 to 2·3 | 2·0 to 2·40 | 0·05      |
| Peine   | 3·60      | 0·60      | 2·25       | 2·70        | 0·05      |
| Kladno  | ...       | 0·44      | 0·40       | 2·00        | 0·03      |

\* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 466–469.

† *Stahl und Eisen*, vol. xiii. p. 105.



metal. Such metal is very easily blown, and the converter lining suffers but little.

**The Best Foundry Iron.**—The Valentine Iron Company, of Bellefonte, Pennsylvania, has been making a wide series of experiments to arrive at the best all-round iron for foundry practice.\* As the results of these experiments the following is given as the range within which the pig iron should run, varying somewhat for light or heavy work :—

|              |                   |                  |              |              |               |
|--------------|-------------------|------------------|--------------|--------------|---------------|
| Silicon.     | Graphitic Carbon. | Combined Carbon. | Manganese.   | Phosphorus.  | Sulphur.      |
| 2·50 to 3·75 | 2·75 to 3·25      | 0·25 to 0·75     | 0·30 to 0·70 | 0·40 to 0·80 | not over 0·06 |

Some of the finest machine-borings obtained from a sewing-machine company showed the analysis of the casting to be as follows :—

|          |                   |                  |            |             |          |
|----------|-------------------|------------------|------------|-------------|----------|
| Silicon. | Graphitic Carbon. | Combined Carbon. | Manganese. | Phosphorus. | Sulphur. |
| 2·82     | 3·36              | 0·16             | 0·67       | 0·60        | 0·05     |

A recent experiment made by the company shows the chemical change which takes place in the cupola. In this instance the melt was made with a 48-hour coke having 1·46 per cent. of sulphur—too high. This will explain the increase of sulphur in the casting. The annexed table shows the analyses of the pig iron used, and of the resulting castings—one a heavy piece of machinery and the other a thin plate  $\frac{1}{16}$ th of an inch in diameter :—

| Description.               | Pig Iron. | Large Castings. | Small Castings. |
|----------------------------|-----------|-----------------|-----------------|
|                            | Per Cent. | Per Cent.       | Per Cent.       |
| Silicon . . . . .          | 2·680     | 2·610           | 2·380           |
| Graphitic carbon . . . . . | 3·140     | 3·420           | 2·980           |
| Combined carbon . . . . .  | 0·740     | 0·100           | 0·430           |
| Manganese . . . . .        | 0·654     | 0·397           | 0·490           |
| Phosphorus . . . . .       | 0·508     | 0·530           | 0·502           |
| Sulphur . . . . .          | 0·041     | 0·089           | 0·087           |
| Iron . . . . .             | 92·230    | 92·850          | 93·130          |

Mr. C. Jones† considers the general characteristics of pig iron and its grading. He gives the following as a typical Pennsylvania foundry pig iron :—

|           |                  |          |             |            |          |
|-----------|------------------|----------|-------------|------------|----------|
| Graphite. | Combined Carbon. | Silicon. | Phosphorus. | Manganese. | Sulphur. |
| 3·75      | 0·20             | 2·50     | 0·75        | 0·30       | 0·06     |

\* *Iron*, vol. xli. p. 384.  
† *Iron Age*, vol. li. pp. 180–182.





0·85 per cent. less manganese than No. 1. Still poorer (by 0·87 per cent.) is specimen No. 3, taken from the front side (cast surface). On the manganese contents of this specimen, No. 4, from the opposite side (fracture surface), bored at almost the same height, shows a decline of 0·93 per cent.

**Ferromanganese and Ferro-silicon from Witkowitz.**—Samples of these materials made at this Austrian works have been found to contain : \*—

|                       | Mn.   | Si.   | P.    | C.    |
|-----------------------|-------|-------|-------|-------|
| Ferro-manganese . . . | 83·09 | ...   | 0·027 | ...   |
| Ferro-silicon . . .   | 2·95  | 12·22 | 0·232 | 2·936 |

**Ferro-tungsten.**—Mr. W. H. Wahl† has examined a series of tungsten alloys possessing considerable hardness and toughness, an extremely fine crystalline texture, and a specific gravity ranging between 9·3 and 10·14. Some of the fractures exhibited the fact that the alloy was not homogeneous, the presence being observed of what are apparently smooth cleavages of imperfect crystals scattered through the finely crystalline matrix of the alloy. A sample of the alloy of 10·14 specific gravity exhibited on analysis a very high percentage of tungsten, and its behaviour towards liquid and fused solvents proved the interesting fact that a large proportion of the tungsten was present in the uncombined condition crystallised in the matrix of the alloy. The analytical results were as follows :—

| C.   | P.    | Si.  | Mn.   | Fe.   | W. (metal). | W. (alloy). |
|------|-------|------|-------|-------|-------------|-------------|
| 0·85 | 0·041 | 0·14 | trace | 42·28 | 22·54       | 34·35       |

Calculation shows that the figures representing the compound  $\text{Fe}_4\text{W}$  are almost identical with the ratio of the iron and combined tungsten, and this ratio appears to represent the saturation point of iron for tungsten.

### III.—*FOUNDRY PRACTICE.*

**Foundry Construction.**—A series of drawings have been published‡ illustrating the plan and general construction and arrangements

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 21.

† *Journal of the Franklin Institute*, vol. cxxxiv. pp. 470-472.

‡ *L'Industria*, vol. vi. pp. 563-568.



**The First American Casting.**—Mr. C. H. J. Woodbury \* refers to the first American casting. This is an iron pot made at the Saugus Ironworks, Lynn, Massachusetts, in 1642. This pot was presented at the time to the then owners of the land on which the foundry had been erected, and has now been presented by a descendant to the city of Lynn. The original ironworks contained a blast-furnace, in which bog iron ore was smelted, with charcoal as a fuel and calcined oyster-shells as a flux. Castings were made directly from the metal flowing from the blast-furnace into a pool, whence it was dipped by crucibles and poured into the moulds. The ordinary cupola was not invented until 1790.

**Machine Moulding.**—The various improvements in moulding are shortly traced by Mr. H. Tabor,† and a reference is made to the neglect with which the foundry is treated as compared with the fitting-shop, where new machines are in constant use. There are now a number of moulding-machines in use operated by belts and cams, by hydraulic, pneumatic, and steam pressure. All ramming-machines may be said to have platens, of which there are two types, rigid and flexible. The latter yields to irregular depths, and exerts an even pressure over the mould. It is made in two forms—first the water bag, a box with a flexible bottom filled with water, and second a group of rammers independently hung on equalising levers. Owing to the friction of the sand on the sides of the flask, more pressure is required at the edges, and a series of experiments have been made by Mr. A. B. Moore to determine the friction in the sand itself and against the box. The author then gives a description of the Tabor moulding-machines, and discusses the question of their employment.

**A New Method of Melting and Casting.**—Mr. G. A. Poyson ‡ describes the Taussig process of melting and casting metals. The metal is melted by the electric arc in a vessel exhausted of air, metal electrodes being used. The moulds are also exhausted. Castings are said to have given good results.

\* *Iron Age*, vol. 1. p. 1104, with illustration.

† *Transactions of the American Society of Mechanical Engineers*, vol. xiii. pp. 537-556.

‡ *Iron*, vol. xli. p. 252.













jected and the means available for strengthening cast iron rolls. Some experimental rolls have been at work, in which a number of wrought steel bars are cast into the barrels near the outer circumference. Numerous illustrations are given.

**Rolling-Mill Engines.**—Drawings of a pair of high-pressure, non-condensing, reversing mill engines for the Melyn Tin-plate Works have been published.\* The engines have cylinders 40 inches in diameter, and the stroke is  $4\frac{1}{2}$  feet. Joy's valve gear is used.

The new engines for the universal slabbing-mill of the Pennsylvania Steel Company consist of a pair of 42 by 60 inch reversing engines geared to drive the horizontal rolls, and a pair of 26 by 30 inch reversing engines, directly connected to the driving shaft of the vertical rolls. The gears are of steel, 36-inch face inside of shrouding, 8-inch pitch, and are 4 feet and 10 feet pitch diameter. These engines are all rigidly connected on a continuous bed, and occupy a space 63 feet long. They weigh 300 tons.†

**Steam-Hammers.**—Several illustrations of steam-hammers have recently been published.‡ One of these is a small hammer with A standards, and the other is a ten-ton hammer with a bow frame without slides, which gives plenty of room for the manipulation of heavy and intricate forgings.

**Steam Forging-Press.**—An illustration has been given§ of a forging-press in which steam is used instead of hydraulic power. With steam at 60 lbs., the press can exert a pressure of 100 tons. There are two cylinders, superimposed, the piston-rod of the lower working through the upper piston.

\* *The Engineer*, vol. lxxiv. pp. 482, 490.

† *Iron Age*, vol. li. p. 568.

‡ *Iron*, vol. xl. p. 443, vol. xli. pp. 69-70.

§ *Ibid.*, vol. xli. pp. 288-289.

# PRODUCTION OF STEEL.

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### I.—THE CARBURISATION OF MALLEABLE IRON.

**Austrian Crucible Steel.**—Dr. E. Przywoznik \* gives the following results of analyses of crucible steel :—

|                           | 1.        | 2.        | 3.        | 4.        |
|---------------------------|-----------|-----------|-----------|-----------|
|                           | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Combined carbon . . . . . | 0·83      | 1·062     | 2·072     | 1·780     |
| Silicon . . . . .         | 0·08      | 0·187     | 0·700     | 0·560     |
| Phosphorus . . . . .      | 0·03      | 0·016     | 0·030     | 0·038     |
| Sulphur . . . . .         | 0·02      | 0·013     | 0·011     | 0·024     |
| Manganese . . . . .       | 0·31      | 0·160     | 1·539     | 0·760     |
| Copper . . . . .          | 0·04      | 0·010     | 0·010     | trace     |
| Chromium . . . . .        | 2·50      | ...       | ...       | 1·340     |
| Tungsten . . . . .        | ...       | 0·447     | 6·140     | ...       |
| Iron . . . . .            | 96·18     | 98·105    | 89·498    | 93·498    |

Crucible steel (1) from the Austrian Alpine Company, (2) from Böhler Brothers in Vienna, (3) tungsten steel from Kapfenberg, and (4) chromium steel from the Austrian Alpine Company.

### II.—THE OPEN-HEARTH PROCESS.

**Mild Open-Hearth Steel for Castings.**—Messrs. A. B. Winder and J. D. Brunton † give a full description of a heat made in a small acid-lined open-hearth furnace at the Sheffield Technical School.

\* *Berg- und Hüttenmännisches Jahrbuch der k.k. Bergakademien*, vol. xl. pp. 471–473.  
† Paper read before the Sheffield Technical School Metallurgical Society; *Iron*, vol. xli. pp. 334–335.

The furnace was charged at 5.55 p.m. with 240 lbs. chrome scrap, containing 1 per cent. of chromium ; 344 lbs. of scrap ; 220 lbs. of chrome pig iron, containing 5 per cent. of chromium and 3 per cent. of silicon ; and 791 lbs. of Millom hæmatite pig iron. The composition of this pig iron and the initial composition of the charge were as follows :—

| Carbon. | Silicon. | Manganese. | Sulphur. | Phosphorus. | Chromium. |
|---------|----------|------------|----------|-------------|-----------|
| 3.83    | 1.2      | 0.5        | 0.04     | 0.045       | ...       |
| 2.83    | 1.0      | 0.5        | 0.05     | 0.070       | 1.0       |

The charge took 110 minutes to melt, and was tapped at 12.20. Ore was added in three lots of 56 lbs. each, at 7.50, 8.50, and 11.5 p.m. Ferromanganese was added at 12.5 and 12 oz. of aluminium was placed in the ladle before tapping.

The composition of the red hæmatite ore used was as follows :—

| Fe <sub>2</sub> O <sub>3</sub> . | MnO <sub>2</sub> . | Al <sub>2</sub> O <sub>3</sub> . | CaO. | MgO. | SiO <sub>2</sub> . | P <sub>2</sub> O <sub>5</sub> . | SO <sub>3</sub> . |
|----------------------------------|--------------------|----------------------------------|------|------|--------------------|---------------------------------|-------------------|
| 81.5                             | none               | 0.84                             | 0.93 | 0.11 | 16.12              | 0.042                           | 0.2               |

And the ferromanganese had the composition—

| Carbon. | Silicon. | Manganese. | Sulphur. | Phosphorus. | Iron. |
|---------|----------|------------|----------|-------------|-------|
| 6.8     | 1.1      | 77.7       | 0.01     | 0.3         | 14.0  |

Samples of the bath were taken at the times indicated in the table below, which shows their composition—

|          | I.     | II.    | III.   | IV.    | V.     | VI.    | VII.   | VIII.  | Initial Charge. | Finished Metal. |
|----------|--------|--------|--------|--------|--------|--------|--------|--------|-----------------|-----------------|
|          | P. ct. | P. ct. | P. ct. | P. ct. | P. ct. | P. ct. | P. ct. | P. ct. | P. ct.          | P. ct.          |
| C . . .  | 1.90   | 0.78   | 0.64   | 0.47   | 0.28   | 0.21   | 0.15   | 0.13   | 2.83            | 0.30            |
| Si . . . | 0.40   | 0.26   | 0.04   | 0.06   | 0.03   | 0.1    | 0.15   | 0.02   | 1.00            | 0.10            |
| Mn . . . | 0.30   | 0.03   | 0.02   |        |        | Trace  |        |        | 0.50            | 0.53            |
| Cr . . . | 0.68   | 0.6    | 0.50   | 0.44   | 0.39   | 0.34   | 0.29   | 0.21   | 1.00            | 0.19            |
| Time . . | 7.45   | 8.15   | 8.45   | 9.15   | 9.45   | 10.15  | 10.45  | 11.15  | ...             | ...             |

The furnace was fired with producer gas, analyses of which at various stages are given. The tensile strength of the metal on a two-inch test piece of about half an inch in diameter showed as follows :—

| Tensile Strength.  |       | Elongation. | Reduction of Area. |
|--------------------|-------|-------------|--------------------|
| Tons per Sq. Inch. |       | Per Cent.   | Per Cent.          |
| Unannealed . . .   | 31.5  | 13          | 13.8               |
| Annealed . . .     | 32.71 | 15          | 22.5               |

A bar  $\frac{7}{8}$ -inch square was bent to an angle of 50°, at which it broke.



ones, after the type of the Cowper stove, and these are placed in a similar way at the sides of the furnace. This arrangement was first introduced in England. It is now employed at a number of Continental works, as, for instance, at the Phoenix Works on the Ruhr. The weight of these regenerators being taken up by columns, the bottom is quite free. The smaller regenerators are the less capable of retaining heat, and the direction of the incoming gases requires to be changed at very frequent intervals in order to prevent the furnace being subjected to changes of temperature. The sectional area of the regenerators must vary with the quantity and character of the fuel consumed. In general, for every connected pair of regenerators it is customary to give a sectional area of from 2·5 to 3 square metres for every 100 kilogrammes of coal burnt, and from 1·5 to 2 square metres for the same quantity of brown coal. For every kilogramme of coal burnt per hour the capacity of such a pair of regenerator chambers would be from 0·04 to 0·07 cubic metre, Gruner having estimated it at 60 kilogrammes of bricks, or approximately 0·033 cubic metre, calculating the specific gravity of the bricks at 1·8. The vertical regenerators are rarely built to a greater height above the channels below them than 8 or 10 feet. The author gives various examples illustrating the size of regenerator chamber. At an Austrian works the vertical gas and air regenerators are each of 16·4 cubic metres capacity, serving a twelve-ton furnace. At a German works an eight-ton furnace is served by gas-regenerators of 8·56 cubic metres capacity, and air-regenerators having a capacity of 12·48 cubic metres. The size of the working-hearth must depend on the intended out-turn of the furnace, and its dimensions are also in part determined by the chemical composition of the pig-iron to be treated, the shallower the bath the greater being the surface of the metal exposed to oxidation. Under ordinary circumstances the depth of metal should not exceed about 8 inches, and only in basic-lined furnaces does the depth reach to as much as 20 inches, owing, in this case, to the large quantity of slag that is produced. The bed of the furnace is always formed of iron plates, and the length of the hearth is half as much again as its width. The author next proceeds to give details as to the usual size of the hearth, the following being considered typical:—

|                                                |     |     |     |     |
|------------------------------------------------|-----|-----|-----|-----|
| Capacity of furnace, tons . . . . .            | 7   | 8   | 10  | 12  |
| Surface of the hearth, square metres . . . . . | 8   | 10  | 12  | 14  |
| Length, metres . . . . .                       | 4·2 | 4·4 | 5·0 | 5·4 |
| Breadth, metres . . . . .                      | 1·9 | 2·4 | 2·5 | 2·6 |

the limits being about as follows:—



Schönwälder open-hearth at the Friedenshütte, Upper Silesia. Further details respecting the furnace and its working are published by H. Dowerg,\* the manager of that works. He refers to the various improvements which have been introduced in this furnace, and to the great improvement in the working results which these have brought about, the wear and tear of the furnace being very greatly diminished. The chief modification consists in the use of a number of regenerative chambers in place of the smaller number commonly employed, one for each opening at the upper part of the furnace, each such chamber having its own separate flues leading to the reversing valves, and each such channel being provided with a separate valve, which enables the regenerator to be thrown completely out of use if the wear of the furnace becomes extreme at the point affected by the gases from such regenerator. The description is aided by a number of illustrations showing the arrangements adopted. The arrangement of the flues was far from being a matter of minor importance, and that finally adopted is described by the author. The furnace as now constructed has shown remarkable endurance. The metal made has had the following composition :—

| No. of Heats. | Percentage of Phosphorus. | No. of Heats. | Percentage of Carbon. |
|---------------|---------------------------|---------------|-----------------------|
| 532           | Under 0·05                | 594           | Under 0·1             |
| 162           | 0·05 to 0·08              | 103           | 0·1 to 0·2            |
| 18            | Over 0·08                 | 15            | 0·2 to 0·5            |

After the completion of this campaign the repairs necessary proved comparatively slight, and the furnace was in active operation again after a fortnight's interval.

The same Schönwälder open-hearth has, since the above-mentioned, 712 charges, made another 512 charges† down to February 16, 1893, producing 6598 tons of ingots. After the 365th charge repairs to the roof had to be effected, which required three days to complete. The average number of charges put through in the working day was 3·31, yielding 41·2 tons of ingots. The metal produced was mostly soft, only a small portion for special purposes being made hard. Analysis showed the metal from 435 charges to contain less than 0·1 per cent. of carbon, that from 69 charges from 0·1 to 0·2 per cent. of carbon, while in only 5 charges did the iron contain more than 0·2 per cent. of carbon. The percentage of phosphorus was less than 0·05 per cent. in the ingot metal

\* *Stahl und Eisen*, vol. xii. pp. 989–996, nine illustrations.

† *Ibid.*, vol. xiii. p. 258.





utilise waste gases as well as waste heat. From a detailed theoretical study based on experimental researches with two Siemens furnaces, the author believes that there is considerable economy in favour of the new form.

**The Stanners Closes Steelworks.**—The Stanners Closes Steelworks at Wolsingham were founded in 1864 by Mr. C. Attwood.\* The works chiefly produce steel castings and forgings, and cover about 20 acres of ground. The melting shop contains five regenerative melting furnaces of 8, 4, 4, 3, and 2 tons capacity respectively, and two pot furnaces. The charges consist of steel scrap with about 5 per cent. of pig iron made from Gellivara ores with silicon spiegeleisen or ferro-manganese. An account is also given of the other parts of the works and of the gas producers.

**The Works of the Carbon Steel Company.**—Drawings are published† of the works of the Carbon Iron Company, Pittsburgh, Pennsylvania. The works cover 8 acres of ground in the centre of the city, and owing to the high valuation of the land the utmost use has to be made of it. New works have therefore been erected. The plant includes six open-hearth furnaces, of 30 tons capacity, and two of 15 tons. They are all of the Lash type, having the regenerators in the flue leading to the stack, and at present are all worked with natural gas. There are four soaking pits, or pit furnaces, with holes of unusual size, in connection with a plate and universal mill. In addition to these there are four large heating furnaces used exclusively for blooms and slabs. The soaking-pits, &c., are served by two 10-ton electric cranes, which travel at high speed. In the plate mill the screws are driven by an electric motor. The cooling tables are 375 feet in length from the centre of the mill to the blade of the shear. The rollers are 13 inches in diameter, 6 feet in length, and spaced 2 feet 7 inches between centres. The main shear has a blade of 137 inches, and it is capable of cutting metal up to  $2\frac{1}{2}$  inches thick. A duplicate shear, weighing 185 tons, is in course of erection. The plate mill has three-high rolls, 34 by 124 inches, the middle roll being of the dimensions 20 by 124 inches. There are lifting tables on either side, each having a capacity of 10 tons. The pinions are of steel, and each roll housing weighs 26 tons. The plant includes in addition to this a 124-inch three-high plate mill, a 36-inch universal mill, and a 48-inch sheet mill.

\* *The Engineer*, vol. lxxv. pp. 201–202, with illustrations.

† *Iron Age*, vol. li. p. 560, with detailed plan of works.



Committee observe, should be a large one, with a minimum capacity of 500 tons a day. The cost of erection would be about £200,000.

**Casting Ingots.**—L. Sebenius,\* manager of the Nykroppa Iron-works, Sweden, casts steel into ingot moulds which are pivoted on swinging arms. These arms are then rotated at the rate of 125 revolutions per minute. Centrifugal action causes the ingot moulds, with their steel contents, to assume a horizontal position. In this way the metal is subjected to a certain degree of compression, and sound ingots are said to result.

Mr. F. Korb† describes the properties and mode of production of sound steel ingots and castings.

**Ingot Moulds.**—Illustrations are given‡ of the hydraulic ingot-moulding machine devised by Mr. J. B. D. A. Boulton, which has been in successful use for some four years at Sheffield. This machine will produce 144 ingots, weighing 85 lbs., per day, free from piping. The ingots are cast with a head of 4 or 5 feet, which is then sheared off to the proper length. Hydraulic cylinders are used to raise and lower the ingot mould, which is bottomless, and to shear off the ingot. The waste is stated not to exceed 3 per cent. Ingots from 3 to 3½ inches square and from 18 to 25 inches long are made at Sheffield, and larger machines are in use in the United States.

Mr. J. Riley§ describes a form of ingot mould which has been devised to obviate the difficulties due to the top being smaller than the bottom, as is the general practice. In the usual form, the smaller upper end, which is unsound, does not get so much work put into it as the larger end, where it is not necessary. The crane power required for stripping and other operations in the casting pit is large, and may well be reduced. Moulds with trunnions, so that they can easily be reversed, have been used and abandoned, but no detailed particulars as to their use are available. Mr. Dick proposed that loops should be suspended across the top of inverted moulds and used for withdrawing the ingots, but unfortunately not enough time could be allowed for sufficient cooling, so the crane hook often dragged the loop out of the ingot. This difficulty was

\* *Stahl und Eisen*, vol. xiii. pp. 152–154, four illustrations.

† Paper read before the London Association of Foremen Engineers and Draughtsmen, November 5, 1892.

‡ *Industries*, vol. xiv. p. 156.

§ Paper read before the West of Scotland Iron and Steel Institute, February 17, 1893.



Classified according to their construction the engines are as follows:—

| Country.                      | No. of Works. | No. of Engines. |
|-------------------------------|---------------|-----------------|
| <i>A. Vertical Engines.</i>   |               |                 |
| 1. Rhineland-Westphalia . . . | 3             | 4               |
| <i>B. Horizontal Engines.</i> |               |                 |
| 1. Rhineland-Westphalia . . . | 8             | 13              |
| 2. Austria-Hungary . . .      | 12            | 17              |
| 3. Upper Silesia . . .        | 2             | 2               |

From these figures the following rough generalisations may be drawn:— For Bessemer works the horizontal blowing engines are everywhere preferred to vertical ones, the preference being easily explained by the greater stability required for the great number of revolutions. Beam engines are not used at all, and vertical blowing engines are used only in Rhineland-Westphalia to the extent of some 10 per cent. of the total number. The number of Bessemer steelworks and of blowing engines is practically the same in Rhineland-Westphalia and in Austria-Hungary. The details given in the fifty pages of statistics are the same as those given in the case of the blast-furnace blowing engines.

**The Tudhoe Steelworks.**—An illustrated account of the Tudhoe iron and steel works at Spennymoor has recently been given.\* At these works the Bessemer process was first worked. The steel melting house contains seven acid-lined open-hearth furnaces in line, five of which are of 20 tons capacity, and two of 16 tons. Their charge consists of 25 per cent. of steel scrap, 15 per cent. of ore, and 60 per cent. of pig iron made by the works from Spanish ore. Particulars are given of the gas producers, and of the reheating and soaking furnaces. The cogging and rolling mills are also described, and some details are given of the blast-furnaces.

**The Vizcaya Ironworks, Bilbao.**—During 1892 three Robert converters were put into activity at these works. The nominal capacity of  $2\frac{1}{2}$  tons has been increased in actual practice to  $4\frac{1}{2}$  tons. The number of these converters is to be increased to five, thus raising the capacity of this works to about 80 or 100 tons of steel in the day of

\* *The Engineer*, vol. lxxv. pp. 331-334.



|                                                      | France. |
|------------------------------------------------------|---------|
| Waste of pig iron, 330 to 440 lbs. per ton . . . . . | 10·51   |
| Coal, 330 to 364 lbs. . . . .                        | 1·40    |
| Coke, 88 to 99 lbs. . . . .                          | 1·72    |
| Dolomite, 121 to 132 lbs. . . . .                    | 0·30    |
| Lime, 396 to 419 lbs. . . . .                        | 1·62    |
| Coal tar, 11 to 13 lbs. . . . .                      | 0·42    |
| Refractory materials . . . . .                       | 0·85    |
| Ingots, moulds and bases . . . . .                   | 0·95    |
| Plumbago . . . . .                                   | 0·35    |
| Miscellaneous expenses and repairs . . . . .         | 1·40    |
| Handling waggons and switching . . . . .             | 0·10    |
| Wages . . . . .                                      | 2·09    |
| General expenses . . . . .                           | 0·50    |
| Sinking fund . . . . .                               | 0·50    |
| Ferro-manganese, 11 to 13 lbs. . . . .               | 1·50    |
| Total . . . . .                                      | 23·12   |
| Deduct value of slag . . . . .                       | 3·00    |
| Net cost of converting . . . . .                     | 20·12   |
| Add cost of pig iron . . . . .                       | 52·55   |
| Total cost . . . . .                                 | 72·67   |

The total cost of the ton of ingots at Dudelange is estimated by F. Tordeur at 63·53 francs, and at Longwy at 67·79 francs. The author, in making these estimates, starts with the assumption that a plant of three 10-ton converters, taking metal direct from a blast-furnace plant, could produce 150 tons of ingots in twenty-four hours. The question of the cost of labour is considered in much detail.

C. Palgen \* and F. Tordeur † state that the older Basic bessemer steel-works in Belgium, such as the Angleur Works, had two converters placed opposite one another, and served by a central crane. To obtain an equal outturn as compared with that of the acid process, two such plants were necessary, so that of four converters only one was in constant work. A more economical arrangement consisted in the use of a single pit, with three converters placed in a semicircle around a central crane. This arrangement has been adopted at the Mont-Saint-Martin Works. Such an arrangement can be used with success up to a daily outturn of 250 tons of ingots, but with a greater output than this the American method should be employed, the converters being arranged in pairs around a central crane. This method of arrangement has been employed at the basic Bessemer works at Hayingen, Joeuf, and Dudelange. At Hayingen there are now six converters placed in a straight line, and these

\* *Mémoires de l'Union des Ingénieurs de Lourain*, 1892.

† *Stahl und Eisen*, vol. xiii. pp. 101-111, six illustrations.





These bottoms usually last about 25 charges, though they have withstood up to 50 charges, while the lining of the converter body lasts about 150 or 160 charges. At present nearly the whole of the larger basic Bessemer works use metal taken direct from the blast-furnaces. By doing this the metal, while of similar chemical composition, is much hotter, as consequently is the blow. A saving is also effected of from 7 to 11 per cent. in the coke used, and from 2 to 3 per cent. in the limestone; there are no cupola charges to be met, and the loss of silicon and manganese in the cupola, with a possible enrichment in the sulphur, is also avoided. In this way the saving effected amounts to about 8s. per ton of steel made.

In melting spiegeleisen in a cupola there is a considerable loss of manganese. In one instance the metal before fusion contained 13·50 per cent. of manganese, and afterwards 10·89, the loss of manganese being consequently 2·61 per cent. The composition of the ferro-manganese in use at the Hayingen works for the recarburisation of the ingot metal is as follows:—

| Mn.   | C.   | P.   | S.     | Si.  |
|-------|------|------|--------|------|
| 60·54 | 5·38 | 0·06 | traces | 3·78 |

From 2 to 3 per cent. of ferro-manganese is added at these works in the production of an ingot iron containing 0·10 to 0·18 per cent. of carbon. Hæmatite pig iron is used, which contains—

| Graphite. | Combined Carbon. | P.   | S.     | Mn.  | Si.  |
|-----------|------------------|------|--------|------|------|
| 2·74      | 1·26             | 0·02 | traces | 0·21 | 2·96 |

This pig iron is employed, in admixture with spiegeleisen, in the production of high-carbon ingot steel. A charge to which 10 per cent. of spiegeleisen, containing 15 per cent. of manganese and 1·4 per cent. of the hæmatite pig iron, had been added, yielded a steel containing 0·47 per cent. of carbon, 0·065 of phosphorus, and 0·80 of manganese. Its tensile strength was 39·3 tons per square inch, with an elongation of 11·5 per cent. All the steelworks around Hayingen use exclusively the limestone found in Namur. This limestone contains less than 1 per cent. of silica. Formerly too much lime used to be added to the charge, but now only about the theoretical quantity is employed. At Hørde, where the pig iron used contains 0·58 per cent. of silicon, 14 per cent. of limestone is used, whilst the quantity now added at Peine, with a pig iron containing 0·60 per cent. of silicon, is 15·2 per cent. as compared with 19·5 per cent. in 1883. The percentage employed at Hayingen varies with that



Ingot Steel.

| Carbon.    |           | Phosphorus. |           | Manganese. |           |
|------------|-----------|-------------|-----------|------------|-----------|
| Beginning. | End.      | Beginning.  | End.      | Beginning. | End.      |
| Per Cent.  | Per Cent. | Per Cent.   | Per Cent. | Per Cent.  | Per Cent. |
| 0·38       | 0·40      | 0·081       | 0·146     | 0·865      | 0·685     |
| 0·43       | 0·44      | 0·066       | 0·091     | 0·118      | 0·940     |
| 0·41       | 0·41      | 0·109       | 0·130     | 0·865      | 0·865     |

Ingot Iron.

|      |     |       |       |       |       |
|------|-----|-------|-------|-------|-------|
| 0·16 | ... | 0·092 | 0·117 | 0·720 | 0·470 |
| 0·18 | ... | 0·119 | ...   |       |       |

That portion of the ingot is the most impure where the metal remains longest fluid—that is to say, the centre—the bottom of the ingot being also purer than the top.

M. Palgen gives details as to the cost of manufacture of the ton of basic ingots in Belgium, of which the following is a summary :—

|                                                                         | £  | s. | d. |
|-------------------------------------------------------------------------|----|----|----|
| Pig iron, scrap, and ferro-manganese . . . . .                          | 2  | 3  | 0  |
| Limestone, coke, other fuel, fire-resisting materials, &c., and wages . | 0  | 7  | 3  |
| Converter bottoms and basic lining . . . . .                            | 0  | 1  | 3  |
| General expenses . . . . .                                              | 0  | 3  | 4  |
| Total . . . . .                                                         | £2 | 14 | 10 |

A similar total is arrived at by M. Tordeur, who, taking as a basis for his calculations the prices for coal and coke which ruled in 1892, gives the following total costs at the places mentioned for the ton of basic ingots :—

| Works at             | £ | s. | d. |
|----------------------|---|----|----|
| Charleroi . . . . .  | 2 | 18 | 2  |
| Liège . . . . .      | 2 | 15 | 10 |
| Düdelingen . . . . . | 2 | 10 | 10 |
| Longwy . . . . .     | 2 | 14 | 3  |

Using soaking pits and reversing engines, the cost of rolling varies for sections not less in weight than 30 lbs. to the running yard from 10s. 5d. to about 12s. On the basis of these calculations, and the selling price of the metal made in March 1892, the average profit was 5s. 7d.







with strokes of 60 inches. The heating furnaces are fitted with disc reversing valves, thus doing away with the older or "butterfly" valves. The converters, measured from the centre of the trunnion, are placed at an elevation of about fourteen feet above the general level, enabling a waggon to be run under the nose of the converter when it is being tipped. The melted metal truck running in front of the converter is actuated by a wire rope. The cupolas are so arranged that they practically commence at the level of the charging floor, only a kind of hood existing above it, thus affording great facility for charging. The distance from the blooming mill to the main shears is 100 feet, sufficient to admit of a 2-ton ingot being rolled down to 4 by 4 inches, and sheared without interfering with the rolling of the succeeding ingots.

**The Basic Bessemer Plant of the Pottstown Works.**—A detailed description of the basic Bessemer plant of the Pottstown Iron Company, with a full description of their practice, is given by Mr. J. Hartshorne.\* The basic slag is ground in a ball mill requiring 13 horsepower to drive it. The average output is 20,000 lbs. in ten hours, 70 to 75 per cent. passing through a 150-mesh sieve. The brick-making plant consists of two Gates' breakers, a 96-inch Fisher chaser mill, elevators, dry and wet mixers, and a brick-making machine. The bricks are made direct from limestone, and are fired wet without previous calcination, thereby preventing admixture of ash from the coke. The ovens hold 5000 bricks, or 14,000 lbs. per charge, which is fired for 36 to 38 hours, with a consumption of 2700 lbs. of fuel per ton of burnt bricks. Two continuous limekilns are at present in use. They are 9 feet in diameter, 30 feet high above the furnace, and 8 feet below. External furnaces are used, and the fuel consumption is 300 lbs. of coal per ton of lime, 25,000 lbs. being burnt per twenty-four hours.

Two Wellman producers supply gas for an open-hearth furnace, in which the ordinary pig and scrap process is carried on.

Adjacent to this plant is the grinding and mixing plant for the basic material. The brick is crushed and ground in a Gates' breaker and a mill, and after sifting is mixed with 10 to 12 per cent. of hot tar.

Two cupolas, a third being in the course of erection, are used for melting. They are 10 feet in diameter, and 24 feet high from the charging door to the tapping hole. They have nineteen 6-inch tuyeres 4 feet above the tapping hole, and are fitted with the Greiner attach-

\* *Transactions of the American Institute of Mining Engineers*, October 1892 (advance proof).





cent. of 80 per cent. ferro-manganese is added, and after two-thirds of the charge is poured from 1 to 1.5 per cent. of a 10 per cent. spiegeleisen is thrown into the ladle. Casting is done slowly, metal being also continuously added as it sinks in the mould to obtain solid ingots. The metal rarely rises in the mould. A simple cast iron plug without sand is used as a capping.

During casting two 4-inch 50 lb. ingots are made for testing. These are forged down at a white heat to  $1\frac{1}{4}$  inch square. Two 8-inch lengths are cut off, one is chilled, and the other cooled slowly from a cherry red. Each bar is laid on a V-shaped opening 5 inches wide and  $2\frac{1}{2}$  inches deep, and is then struck light uniform blows by a 650 lb. drop hammer till bent down into the V. It is then reversed, and the process continued until the bar is broken. Cracks and fracture are observed, and from the latter the percentage of phosphorus may be told to within 0.01 per cent. The remainder of the ingot is forged down to  $\frac{5}{8}$ -inch square, and cut into three 10-inch lengths. One of these is chilled, and another cooled slowly. Each of these two is nicked and broken, the longer portion of each being bent in a machine to grade the metal for softness. These tests are confirmatory of the previous two. The third piece is reserved for testing red shortness by a combination bending and drifting process at a bright cherry red heat. These tests not only indicate the quality of the metal, but from them can be determined with great accuracy the duration of blow and the amount of recarburisers required for the next charge. Besides these tests, carbon, manganese, and phosphorus are determined chemically in each heat, and sulphur in every fourth heat.

In conclusion the author gives tables showing the results of consecutive blows.

**Basic Slag as Manure.**—Dr. M. A. von Reis \* finds that hard slags contain more ferric oxide than soft slags which are produced by slow cooling, and are therefore preferable for manurial purposes. This fact is ascribed to the decomposition of calcium ferrate when the slag cools slowly. On solution in dilute hydrochloric acid, the softer slags give a greater amount of residue of ferric oxide, and the quantity that is left is a sign of the ease with which the slag can be ground.

\* *Zeitschrift für Angewandte Chemie*, 1892, pp. 229-231.



|                                     | P.    | S.    | C.   |
|-------------------------------------|-------|-------|------|
| Blooms . . . . .                    | 0·018 | 0·020 | 0·05 |
| Bar iron after re-rolling . . . . . | 0·010 | 0·010 | 0·05 |

The slag contains 24 to 30 per cent. of silica and 30 to 50 per cent. of iron. The loss of iron is high, but has been reduced to 15 per cent. The quality of the product is good, and the process is economical.

In the Adams process the ore is reduced to a sponge by natural gas at a temperature of about 800° C., and is charged almost direct into an open-hearth furnace by means of a shoot. The reducing chambers are vertical, and are placed in groups of four over the furnace. The gas is led through the ore, and then is burnt in passages surrounding the chambers. The ore is charged in lumps the size of the doubled fist, and is reduced in about an hour and a half. The shape of the lumps is preserved, but while the iron is reduced the gangue is not melted until it is introduced into the furnace. A basic open-hearth is used, so that the phosphorus is kept in the slag. The practice is to discharge the four chambers into the hearth, then to add and melt the pig iron, and subsequently to discharge the recharged chambers one at a time into the bath, tapping off the slag from time to time as it clears. One of pig iron to two parts of ore has been successfully employed. This process appears to be preferable to the first one, as the fuel is employed to better advantage in the chambers than in a reverberatory furnace.





















the metal further. The limit of the process, with the machinery as yet built, is tubes of about  $1\frac{1}{2}$  inch in diameter and 16 feet in length.

Mr. W. H. Barraclough \* describes the uses of the Mannesmann tubes and the method of their manufacture. Various explanations of the action are given, and the machinery in use at Landore is described. Tests of the tubes compared with welded or cast pipes are appended.

Mr. G. R. Green † describes the various forms through which machinery for the manufacture of spirally welded tubing has passed. For some nine or ten years prior to 1887 Mr. J. B. Root had experimented on this subject, and in the previous year had constructed a machine in which a few feet of tube could be produced from a skelp. After a short length of tube was made, however, the feeding and other parts refused to act, and many modifications had to be introduced. Some of these are described by the author, and a description is given of the type of machine which is now in successful use, and is turning out pipe far beyond the estimated capacity. An improved type of double draw-bench for making solid-drawn seamless steel tubes has recently been illustrated. ‡

**The Manufacture of Wire.**—Mr. G. P. Clapp § describes the method of manufacture of Bessemer steel wire. All the finer grades of wire are produced from No. 5 or No. 6 rod. Analyses of two different grades of rods showed :—

| Elements.            | I.        | II.       |
|----------------------|-----------|-----------|
|                      | Per Cent. | Per Cent. |
| Carbon . . . . .     | 0·089     | 0·075     |
| Silicon . . . . .    | 0·008     | traces    |
| Phosphorus . . . . . | 0·068     | 0·055     |
| Sulphur . . . . .    | 0·076     | 0·043     |
| Manganese . . . . .  | 0·446     | 0·216     |
| Copper . . . . .     | 0·032     | 0·032     |
| Iron . . . . .       | 99·342    | 99·600    |
| Total . . . . .      | 100·061   | 100·021   |

The material represented by I. made wire of excellent quality, whilst the metal II. was not only brittle but inferior in every way. It was

\* Paper read before the Mason College Engineering Society, December 7, 1892, through *The Engineer*, vol. lxxiv. p. 540.

† *Journal of the Franklin Institute*, vol. cxxxiii. pp. 176–186, with illustrations.

‡ *Iron and Coal Trades Review*, vol. xlvi. p. 619.

§ *Iron Age*, vol. 1. pp. 576–577.





















is a simple lever, which magnifies the stretch four or less times, and the other is connected to a series of levers which altogether magnify the motion from 100 to 500 times. The latter set is automatically disengaged as soon as the electric limit is passed. Each of these sets of levers works a pen over a rotating drum. Several of the curves drawn by this device are shown.

**The Testing of Iron and Steel.**—Mr. T. Morris\* considers engineers' tests of iron and steel from an ironmaster's point of view. A large number of engineers' specifications are tabulated, and their requirements discussed. The elastic limit test is condemned, and reference is made to tensile tests with and across the grain, and to the effect of the length of the test-piece on the elongation. A large number of examples are given to illustrate this, the average being as follows:—

|                                       |     |     |     |
|---------------------------------------|-----|-----|-----|
| Length of test-piece, inches . . . .  | 9½  | 6½  | 3½  |
| Elongation per cent., average . . . . | 6.5 | 7.0 | 8.5 |

To a certain extent there is also a variation in the tensile strength found by taking different lengths of test-pieces. The effect of grain on the strength may be lessened by cross-filing, but there is danger of including slag or cinder. The elastic limit may be the same in very different kinds of iron, as is shown by some results obtained by Mr. B. Marshall:—

| Description.                              | Tensile Strength.     | Reduction of Area. | Elongation in 10 Inches. | Limit of Elasticity. |
|-------------------------------------------|-----------------------|--------------------|--------------------------|----------------------|
|                                           | Tons per Square Inch. | Per Cent.          | Per Cent.                | Tons.                |
| ½-inch plate rolled from puddled bar {    | 18.8                  | 5                  | 4                        | 16.0†                |
| ½-inch plate rolled from ingot iron . . . | 22.6                  | 15                 | 12                       | 15.5‡                |
| ½-inch puddled iron plate . . . . .       | 32.2                  | 24                 | 8                        | 15.7†                |
| 1½-inch Bowling round bar . . . . .       | 18.6                  | 4.5                | 3                        | 13.8                 |
|                                           | 22.7                  | 55                 | 29                       | 13.7                 |

The reduction of area as a test for ductility is well worthy of consideration, as it can generally be easily obtained, whilst the specifications for elongation tests are most confusing. The following standard tests are recommended, no conditions lower than those given being allowed:—

\* Paper read before the South Staffordshire Institute of Iron and Steel Works Managers, February 4, 1893.

† Across grain.

‡ With grain.





edges. One sample only to be taken for every ton of metal tested. If the test is unsatisfactory two other test-pieces are to be tried, and if one of these gives similar unsatisfactory results, the metal is to be rejected.

For metal from 0·28 to 1·10 inch in thickness, the following regulations are to hold good, but for metal of other thickness special test regulations are to be mutually agreed upon:—Longitudinally the tensile strength shall not be less than 23·5 nor more than 27·9 tons per square inch, with an elongation of at least 20 per cent. Across the fibre or grain the tenacity must be at least 22·9, but must not exceed 28·6 tons per square inch, while the elongation must not be less than 17 per cent. For screws and rivets the tensile strength may vary from 22·9 to 26·7 tons per square inch; the elongation must be at least 22 per cent.

With regard to bending tests, the metal should be heated to redness, and then plunged into water having a temperature of about 28° C. It must then be bent round a curve, whose diameter at the bending point is equal, in the case of longitudinally taken test-pieces, to the thickness of the test-piece, and for test-pieces taken across the metal, to double the thickness of the test-piece. In the case of the longitudinal test-pieces no cracks must show, but in the case of the others surface cracks of little importance are permissible. With regard to the tests made at a red heat, punching tests must be made, and a 0·79 inch hole so punched must be widened out to a diameter of 1·18 inch. For rivet or screw metal the test-piece must be bent to an angle one half the thickness of the test-piece without showing cracks, and it must be capable of being hammered down to a third of its length without cracking. Similar tests are also described for rivet and screw metal, for ingot steel, and for steel castings.

Mr. J. Sondericker\* gives a description of some repeated stress experiments. Failure under repeated stress may occur from some molecular change set up in the mass, or may be the outcome of a gradually extending crack. During a year and a half the author has been experimenting with a view to studying the elastic changes produced by such stresses. A test-shaft loaded at points equidistant from the bearings was caused to revolve 500 times per minute until it cracked. At intervals the shaft was stopped and measurements taken with and without the load. Sixteen specimens have been tested, including wrought iron, open-hearth and Bessemer steel, and cold-rolled shafting. The test-bars

\* *Technology Quarterly*, vol. v. pp. 70–80.



| Elements.                   | Commercial Steels. |              | Alloy Steels. |              |
|-----------------------------|--------------------|--------------|---------------|--------------|
|                             | Upper Limit.       | Lower Limit. | Upper Limit.  | Lower Limit. |
|                             | Per Cent.          | Per Cent.    | Per Cent.     | Per Cent.    |
| Carbon . . . . .            | 1.50               | 0.30         | 2.25          | 1.25         |
| Silicon . . . . .           | 0.30               | 0.02         | 1.50          | 0.50         |
| Sulphur . . . . .           | 0.10               | 0.005        | 0.10          | 0.005        |
| Phosphorus . . . . .        | 0.10               | 0.01         | 0.30          | 0.01         |
| Manganese . . . . .         | 1.00               | 0.08         | 15.00         | 5.00         |
| Tungsten . . . . .          | ...                | ...          | 7.00          | 0.50         |
| Chromium . . . . .          | ...                | ...          | 2.00          | 0.25         |
| Oxygen . . . . .            | 0.20?              | traces       | 2.00          | 0.25         |
| Hydrogen and nitrogen . . . | very little        | very little  | 2.00          | 0.25         |

The lower limit indicates those quantities of the elements at which their specific action ceases to be sufficient to give the "alloy steel" special properties.

The lower limit of carbon in commercial steel is given at 0.30, because below this the metal becomes incapable of any notable amount of hardening when suddenly cooled.

The upper limit for oxygen is queried, because there are no wholly satisfactory methods of analysis for this element in the presence of large quantities of iron.

Hydrogen and nitrogen have been found in small quantities in all steels. Carbonic oxide appears likewise to be a universal ingredient of steel.

The author considers that steel really represents merely a solution of certain bodies in iron, and this, too, whether the steel be molten or solid. It is known that all compounds, when in solution, tend to dissociate, and it would seem, therefore, that if definite carbides, oxides, or phosphides were introduced into molten iron they would to a certain extent, at any rate, become dissociated.

The author next proceeds to consider the influence of various elements on iron. Oxygen, he observes, may be dissolved in iron, and its influence is very deleterious. The influence of carbon, both alone and in conjunction with other elements, is also considered, and the question of chilling is dealt with at some length.

The author gives what he terms "equations of annealing" and of "chilling." These are as follows, the chemical composition of the iron forming the basis of the equations:—

$$\text{Tendency to chill} = \frac{C \times Mn}{Si} \times \frac{1}{t}.$$

$$\text{Power of annealing} = \frac{Si}{C \times Mn} t.$$







uniformly 2000 lbs. too high, and 94 per cent. were within 5000 lbs. To allow for variation in the size of the plates from which the tests are taken, the following table is given, compiled from the results given by the author:—

| Thickness. | Under 70 Inches. | 70 to 85 Inches. | Over 85 Inches. |
|------------|------------------|------------------|-----------------|
| Inch.      | Lbs.             | Lbs.             | Lbs.            |
| 1          | - 5000           | - 4000           | - 3000          |
|            | - 4000           | - 3000           | - 2000          |
|            | - 3000           | - 2000           | - 1000          |
|            | - 2000           | - 1000           | ...             |
|            | - 1000           | ...              | + 1000          |
|            | ...              | + 1000           | + 2000          |
|            | + 2000           | + 3000           | + 4000          |

The results of these investigations are also given in a graphic form.

**Endurance of Tempered Steel.**—Mr. W. A. Doble\* of San Francisco has published the results of a series of experiments to ascertain the effect of blows systematically given on the ends of sections of steel bars, set in an anvil or heavy casting, the sledges being swung by men striking in time and with full force. The third column relates to a degree of temper at present adopted by the A. Doble Company as that of highest resistance, and which is not easy to define, further than it is a mean between the malleable and friable state of the steel, and belongs to what is technically called “blue tempers.” The scheme of such trials was suggested by the former rapid destruction of various implements made by the Company, such as wedges, drifts, drills, chisels, and so on, due to their being frayed, split, and upset at the top, also to determine the effect upon hammers and sledges as the implements struck were increased in hardness.

| Description.                          | Steel Forged, not Tempered. | Mild Temper. | Standard Temper of Doble Co. |
|---------------------------------------|-----------------------------|--------------|------------------------------|
| Size of test-plug . . . . .           | 1½ in. sq.                  | 1½ in. sq.   | 1½ in. sq.                   |
| Duration of test in hours . . . . .   | 1                           | 4            | 4                            |
| Number of sledges . . . . .           | 3                           | 3            | 3                            |
| Weight of sledges . . . . .           | 10 lbs.                     | 12 lbs.      | 12 lbs.                      |
| Number of blows . . . . .             | 5,000                       | 19,000       | 19,000                       |
| Original length, inches . . . . .     | 5½                          | 5¾           | 5½                           |
| Present length, inches . . . . .      | 5¾                          | 5¾           | 5½                           |
| Reduction in length, inches . . . . . | ¾                           | ¾            | ¾                            |

\* *Iron Age*, vol. 1. p. 1160.





done slowly and uniformly. Hammering should be done with care, and not at all in the cold, as it promotes brittleness. No complete remedy has been found for bubbles or flaws. Forging to shape by the hydraulic press, and tempering, are referred to.

**Boiler Plate.**—At the November Meeting of the American Society of Mechanical Engineers, Mr. F. H. Daniels\* described a boiler explosion in which one of the plates in the third row, just over the most intense heat, “bagged” and ruptured, leaving an orifice about 1 inch in diameter, in which the metal around the orifice had thinned to a knife edge. Analysis showed the plate to contain:—

| Phosphorus. | Sulphur. | Silicon. | Manganese. | Carbon. |
|-------------|----------|----------|------------|---------|
| 0·063       | 0·022    | 0·024    | 0·261      | 0·100   |

This plate, when originally tested, was found to possess a tensile strength at one end of 68,050 lbs. per square inch, and at the other end of 65,550 lbs. After rupture, the tensile strength of the plate in the immediate vicinity of the bulge was 61,666 lbs. per square inch, with a reduction of area of over 32 per cent., and at the part of the plate farthest from the bulge 60,486 lbs., with a reduction of area of 41 per cent. These test-pieces were, however, not perfectly straight ones, owing to the bulge.

Mr. A. J. Dubston† has made a large number of experiments on the transmission of heat through plates in connection with the tube-plates of boilers. Some note is also taken of the material employed for the tubes.

**Maryland Rail Steel.**—Details are published‡ which relate to a number of blows made by the Maryland Steel Company, United States. The carbon contents of the metal treated varied between 0·34 and 0·40. The following are analyses of the metal made:—

| Heats.        | Silicon.  | Phosphorus. | Manganese. | Carbon.   | Sulphur.  |
|---------------|-----------|-------------|------------|-----------|-----------|
|               | Per Cent. | Per Cent.   | Per Cent.  | Per Cent. | Per Cent. |
| 12,106–12,122 | 0·000     | 0·085       | 1·00       | ...       | 0·030     |
| 12,123–12,143 | 0·056     | 0·073       | 1·07       | 0·408     | 0·043     |
| 12,144–12,164 | 0·052     | 0·082       | 1·03       | ...       | 0·051     |
| 12,165–12,185 | 0·060     | 0·085       | 0·96       | 0·396     | 0·089     |
| 12,186–12,204 | 0·028     | 0·081       | 0·93       | ...       | 0·066     |

\* *Iron Age*, vol. 1. p. 1084.

† Paper read before the Institution of Naval Architects, March 22, 1893.

‡ *Iron Age*, vol. li. p. 670.



one feature that is especially desirable, as breakages of wheels or axles can generally be traced to inferior material, faulty manipulation, or bad design. Steel axles are often condemned because the broken ones show a less mileage than broken iron axles, but it is found that steel axles have a much longer life than iron ones when both are sound.

An account of the fracture of railway tires on the German State railways from 1884 to 1890 is given by Bork.\* The fractures averaged 0·28 per cent. of the wheels used in these seven years. In locomotive wheels the fractures were 0·5 per cent., in tender wheels 0·65, and in passenger vehicles 0·38 per cent. The fractures largely depended on the thickness, as shown below :—

|                     |   |                |                |                |                |      |      |      |
|---------------------|---|----------------|----------------|----------------|----------------|------|------|------|
| Thickness in inches | { | Over 2·362     | 1·968 to 2·362 | 1·575 to 1·968 | 1·378 to 1·575 |      |      |      |
|                     |   | 1·181 to 1·378 | 0·984 to 1·181 | 0·787 to 0·984 |                |      |      |      |
| Fractures per cent. |   | 0·025          | 0·08           | 0·29           | 0·54           | 1·05 | 1·65 | 1·85 |

Much information is given in the course of a series of articles on the construction of the modern locomotive † about the use of steel castings for that work. At the present time there is much difference of opinion among engineers as to the tests required and the specifications for the materials. A number of tables given show analyses of steel and the results of various tests on different steels, with the effect of annealing and other treatment. The manufacture of forgings is also dealt with at some length, especial attention being paid to the manufacture of tires and cranks.

**Locks and Safes.**—In describing the construction of locks and safes, Mr. H. W. Chubb ‡ gives a short and interesting history of these articles, and illustrates the various artistic and useful forms that they have assumed. In dealing with safes, some account of the metal used is given. In American burglar-proof safes, several thicknesses of steel of different degrees of hardness are used, and all joints are closed or covered with forged bands. To give extreme hardness, metal similar to spiegeleisen and capable of being chilled is sometimes run in between the inner and outer plates. In England compound plates made by rolling ingots with alternate hard and soft layers are often employed, five layers often being used. Safemakers look with considerable interest on the experiments of metallurgists in the production of steel alloys so as to obtain a perfectly

\* *Verhandlungen des Vereins für Eisenbahnkunde*, 1892, p. 48.

† *The Engineer*, vol. lxxiv. p. 25-28, &c., vol. lxxv. pp. 157, 158, &c.

‡ *Journal of the Society of Arts*, vol. xli. pp. 510-528.







and an elongation of at least 25 per cent., combined with a reduction of area of not less than 50 per cent.

**Basic Bessemer Steel Joists.**—Some tests have recently been made \* by direct loading to ascertain the strength of some basic Bessemer steel joists. The particulars are as follows :—

| Scantlings.                       | Web.                   | Span.       | Material.         |                         | Load Distribution on Failure. | Strain in Flanges at Failure. |
|-----------------------------------|------------------------|-------------|-------------------|-------------------------|-------------------------------|-------------------------------|
|                                   |                        |             | Tensile Strength. | Elongation on 8 Inches. |                               |                               |
| Inches.<br>12 × 6 × $\frac{3}{4}$ | Inch.<br>$\frac{3}{8}$ | Feet.<br>15 | Tons.<br>29·6     | Per Cent.<br>25·5       | Tons.<br>50                   | Tons.<br>21                   |
| 10 × 6 × $\frac{3}{8}$            | $\frac{1}{2}$          | 15          | 27·7              | 24·0                    | 34½                           | 21                            |

**Manganese Steel.**—Mr. H. M. Howe † again refers to the researches of Tetskichi Mukai on manganese steel, giving the analysis of the steels examined by him, with some further calculations from his data on the composition of the mother mass. The effects of sudden cooling on manganese and on carbon steel are tabulated as follows:—

| Property.                                               | Effect of Sudden Cooling. |                                        | Effects in the Two Steels. |
|---------------------------------------------------------|---------------------------|----------------------------------------|----------------------------|
|                                                         | In Case of Carbon Steel.  | In Case of Manganese Steel.            |                            |
| Hardness . . . . .                                      | Increase, enormous        | Increase, slight if any                | Like                       |
| Percentage of the total carbon in the hardening state } | Increase, very great      | Increase, moderate ‡                   | Like                       |
| Density . . . . .                                       | Decrease                  | In one case, increase<br>„         nil | } Opposite                 |
| Size of grain . . . . .                                 | Nil, or decrease          | Increase                               | Opposite                   |
| Separation of components .                              | Decrease                  | Increase                               | Opposite                   |
| Ductility . . . . .                                     | Decrease, enormous        | Increase, enormous                     | Opposite                   |
| Tensile strength . . . . .                              | Increase                  | Increase                               | Like                       |

Manganese steel, whether cooled quickly or slowly, appears to consist of a mother mass and a carbide, with an approximate composition,  $\text{Fe}_{10}\text{Mn}_3\text{C}_5$ . In the quenched steel there is more of the mother mass, which also contains more carbon. The slight variation in the amount of the two constituents can hardly account for the increase of ductility, and the increase of combined carbon in the mother mass acts in a directly

\* *Engineering*, vol. lv. p. 653.

† *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).

† Moderate, compared with the increase in the case of carbon steel.





The United States Government has decided to test the use of nickel-steel in the manufacture of machinery. To this end a section of the propeller shafting of the *Brooklyn* is to be made of nickel-steel, and the United States sea-going battleship No. 1 is to be similarly provided with such shafting.\*

**Tests of Armour Steel and Armour Plates.**—The specifications for the armour of the new United States battleships state that the steel must contain  $3\frac{1}{2}$  per cent. of nickel. The weight of the ingot must be at least double that of the finished plate, and in no case must the mean cross-section of the ingot be allowed to fall during preliminary treatment to less than three times the width of the finished plate. At least 30 per cent. of the weight of the ingot is to be discarded from its upper end if the ingot has been cast in the ordinary way, or 5 per cent. if fluid compressed ingots are used in the manufacture of hollow armour forgings. In physical tests the tensile strength of plates to be Harveyised must be at least 65,000 lbs. to the square inch, with 12 per cent. elongation. For plates not intended for the Harvey process, but which are to be oil-hardened and annealed, each specimen shall show not less than 75,000 lbs. per square inch tensile strength, and 10 per cent. elongation. Four test-specimens are to be taken from each plate after forging or rolling, and before any further treatment except annealing: one longitudinal and one transverse specimen from each end of the plate. The ballistic test is considered the one of greatest importance, and the method of performing this is discussed. The Government requires that there shall be no crack extending from the point of impact to an edge of the plate, and at the same time through the entire thickness of the plate, at an edge, and neither the projectile itself, nor any part of it, shall pass entirely through the plate and its oak backing.†

A nickel-steel armour plate was tried at Indian Head on February 11. The plate was 9 by 7 feet, and 14 inches in thickness. Four shots were fired with striking velocities of 1472, 1860, 1960, and 2000 feet per second. The first entered 5 inches and broke up, the second and third both penetrated about  $6\frac{1}{2}$  inches and partly cracked the plate, and the fourth shot entered about 10 inches, and cracked the plate in several directions, also breaking the backing.‡

Tests were made, on March 22, near Bethlehem, Pennsylvania, of a

\* *Iron Age*, vol. l. p. 1025.

† *Ibid.*, vol. li. pp. 417-419.

‡ *Engineering and Mining Journal*, vol. lv. p. 155; *Industries*, vol. xiv. pp. 278-279.



## CHEMICAL PROPERTIES.

**The Classification of Steel.**—A. Semlitsch\* observes that the classification of steel and ingot iron, for which it is customary in Austria-Hungary to adopt the Tunner scale, is subject elsewhere to very considerable variation, as will be seen from the following table :—

| No. | Hardness.                | Scale.                         |                                 |                                 |                              |
|-----|--------------------------|--------------------------------|---------------------------------|---------------------------------|------------------------------|
|     |                          | Tunner,<br>Carbon<br>per Cent. | Eggertz,<br>Carbon<br>per Cent. | Zeltweg,<br>Carbon<br>per Cent. | Neuberg, Carbon<br>per Cent. |
| 2.  | { Medium<br>Soft         | 1·25<br>1·17                   | 1·25<br>1·08                    | ...<br>...                      | ...<br>...                   |
| 3.  | { Hard<br>Medium<br>Soft | 1·08<br>1·00<br>0·92           | 1·00<br>0·92<br>0·83            | ...<br>...<br>...               | } From 1·12 to 0·88          |
| 4.  | { Hard<br>Medium<br>Soft | 0·83<br>0·75<br>0·67           | 0·75<br>0·67<br>0·58            | 0·837<br>0·772<br>0·652         |                              |
| 5.  | { Hard<br>Medium<br>Soft | 0·58<br>0·50<br>0·42           | 0·50<br>0·42<br>0·33            | 0·557<br>0·503<br>0·451         |                              |
| 6.  | { Hard<br>Medium<br>Soft | 0·33<br>0·25<br>0·17           | 0·25<br>0·17<br>0·13            | 0·374<br>0·295<br>0·207         | } From 0·38 to 0·15          |
| 7.  | { Hard<br>Medium<br>Soft | 0·13<br>0·05<br>...            | ...<br>...<br>...               | 0·183<br>0·145<br>0·127         |                              |

**Segregation in Steel.**—Mr. T. W. Hogg† gives a large number of analyses of metal from different portions of a mild steel cylindrical ingot weighing 11 tons 1 cwt., 10 feet long and 30 inches in diameter :—

\* From the Hungarian, through the *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 2.

† *Journal of the Society of Chemical Industry*, vol. xii. pp. 236–239.



and 0·30 per cent. of manganese, and more malleable though still brittle specimens gave :—

|                    | Fe.   | Combined<br>C. | Graphitic<br>C. | Si.  | Mn.  | S.   | P.   |
|--------------------|-------|----------------|-----------------|------|------|------|------|
| Globules . . .     | 94·70 | 1·00           | 2·54            | 0·68 | 0·20 | 0·17 | 0·14 |
| Original steel . . | ...   | 0·35           | traces          | 0·30 | 0·80 | 0·04 | 0·05 |

On breaking pigs, a fine-grained patch is often found near the centre, an analysis of which compared with the exterior is given below :—

|              | Mn.  | Combined<br>C. | Graphitic<br>C. | Si.  | S.    | P.    | Cu.  |
|--------------|------|----------------|-----------------|------|-------|-------|------|
| Centre . . . | 0·92 | 2·93           | 0·39            | 2·42 | 0·036 | 0·033 | 0·10 |
| Exterior . . | 0·91 | 3·60           | 0·44            | 2·42 | 0·036 | 0·033 | 0·10 |

A similar appearance is often seen in the gits of steel castings, but this is due to the recarburisation of the exterior by the charcoal blacking thrown on the top of the feeder.

Mr. W. E. Koch \* gives an analysis of open-hearth steel rails showing segregation. The analytical results were as follows :—

|                      | At Surface. | 1 Inch from Surface. |
|----------------------|-------------|----------------------|
| Carbon . . . . .     | 0·13        | 0·15                 |
| Phosphorus . . . . . | 0·28        | 0·46                 |
| Sulphur . . . . .    | 0·06        | 0·06                 |
| Manganese . . . . .  | 0·60        | 0·62                 |

In steel plates similar conditions have been observed. The following shows the composition of one that cracked after having been built into a boiler in 1880 :—

|                      |              |
|----------------------|--------------|
| Carbon . . . . .     | 0·07 to 0·13 |
| Sulphur . . . . .    | 0·08 to 0·15 |
| Phosphorus . . . . . | 0·04 to 0·06 |
| Manganese . . . . .  | 0·60 to 0·68 |

This plate was rolled from a slab hammered out of an ingot about 18 inches thick.

Other experiments with plates rolled from large ingots showed a distinct segregation of phosphorus, sulphur, and carbon at the centre of the plate.

**The Solubility of Carbon in Iron.**—H. Moissan † states that if iron is saturated with carbon at temperatures varying between 1100° and 3000° C., different results are obtained at the different temperatures.

\* *Proceedings of the Engineers' Society of Western Pennsylvania*, vol. ix. No. 2, pp. 23-26.  
† *Comptes Rendus de l'Académie des Sciences*, vol. cxvi. p. 218.



**The Action Exerted by Iron on Carbonic Oxide.**—The question of the action of finely divided iron and manganese on carbonic oxide has been studied by Guntz, and his observations are discussed by C. G. Särnström.\* At a temperature of  $500^{\circ}$ , it has been shown by Stammer that a current of carbonic oxide will reduce ferric oxide with the deposition of amorphous carbon. Schützemberger, on the other hand, has pointed out that carbonic oxide free from carbonic anhydride, if passed over iron, is decomposed with the formation of C and  $\text{CO}_2$ . By distilling *in vacuo* at a temperature of  $250^{\circ}$  or  $280^{\circ}$  their amalgams, best obtained electrolytically, both iron and manganese are left in a very finely divided condition. If a current of carbonic oxide be passed over these metals heated in a glass tube, the carbonic oxide is found, as has been shown, to enter into combination with them, being absorbed at first without evolution of gas, the reaction probably being  $\text{Mn} + \text{CO} = \text{MnO} + \text{C}$ , or  $\text{Fe} + \text{CO} = \text{FeO} + \text{C}$ . Other reactions also take place, as Moissan has shown, such as  $2\text{Mn} + \text{CO}_2 = 2\text{MnO} + \text{C}$ , all explaining the deposition of carbon. Särnström refers especially to Sir Lowthian Bell's experiments, the results of which were published in the first volume of the *Journal of the Iron and Steel Institute*, which are practically identical with those referred to by the author.

**Oxygen in Malleable Iron.**—Mr. P. Gladky† discusses the part that is played by the oxygen which is present in malleable iron. The author assumes that of the various impurities present in this metal, any metallic ones will exist as alloys with iron that are dissolved in the mass of metal. These, he considers, exert an entirely different kind of influence on the iron to that which is exerted by the metalloids. These latter enter into chemical combination with the iron, and place themselves between its molecules. If, for instance, 0.08 per cent. of sulphur is present, this represents 0.22 per cent. of iron sulphide, and one is therefore justified rather in referring to the influence exerted by the iron sulphide than to that of the sulphur as such. This appears, too, to be the more justifiable when it is remembered that a percentage of 0.22 of slag in the metal would exert a similar influence. Hard metals, the author thinks, harden iron, because they themselves are hard, while a metal such as copper does not deleteriously affect the properties of malleable iron, because it in itself is a malleable and ductile metal. On the

\* *Teknisk Tidskrift*, vol. xxiii. p. 61.

† From the *Russian Mining Journal*, vol. ii., 1892, p. 72; through *Stahl und Eisen* vol. xiii. pp. 245 and 293.









**A Crystalline Iron-Tungsten Alloy.**—T. Poleck and B. Grützner\* found that a lump of iron-tungsten alloy, obtained by an electrolytic method from wolfram, from Bohemia, consisted of a crystalline matrix of the composition  $\text{Fe}_2\text{W}_3\text{C}_3$ , containing small crystals of the composition  $\text{FeW}_2$ . Both the crystals, which are prisms of the hexagonal system, and the matrix are silver-grey in colour, very heavy, and as hard as corundum. The specific gravity of the matrix is 12.92 to 13.04.

**The Alloys of Iron and Tin.**—From a study of the formation of the alloys of tin and iron, Mr. W. P. Headden † concludes that there is a series of stannides of iron, of which he obtained the following members:— $\text{FeSn}_2$ ,  $\text{Fe}_2\text{Sn}_3$ ,  $\text{Fe}_2\text{Sn}_4$ ,  $\text{Fe}_4\text{Sn}_5$ ,  $\text{Fe}_5\text{Sn}_6$ ,  $\text{FeSn}$ ,  $\text{Fe}_3\text{Sn}$ ,  $\text{Fe}_4\text{Sn}$ , and  $\text{Fe}_9\text{Sn}$ . Some of these have been described before, but the published descriptions assign to them properties some of which differ widely from those observed by the author. All writers on these alloys agree in giving aqua regia as the solvent for them. The author, however, has invariably used hydrochloric acid, and has found but a small amount of any one of them insoluble in this agent, and the portion insoluble in it was almost as insoluble in aqua regia. The description of the crystal forms is also quite at variance. This may be due to a difference of interpretation of the forms, or it may indicate that the alloys vary greatly, both in form and in properties, according to the conditions under which they are produced. The author's observations tend to establish the latter theory.

**An Iron-Nickel Alloy.**—Mr. D. H. Brown, ‡ on breaking a pot of copper-nickel matte, found a cavity lined with brilliant tin-white crystals. They were highly magnetic, exceedingly tough and flexible, and only sparingly soluble in hydrochloric or sulphuric acids. In hot dilute nitric acid they were, however, readily soluble, leaving no siliceous or carbonaceous residue. On analysis, the crystals were found to have the following composition, which, if the copper be excluded, as it appeared to be partly mechanically included, would correspond to the formula  $\text{Fe}_8\text{Ni}_9$ :—

| Copper. | Iron. | Nickel. |
|---------|-------|---------|
| 4.89    | 43.3  | 52.1    |
| 3.64    | 44.0  | 52.0    |

\* *Berichte der Deutschen Chemischen Gesellschaft*, vol. xxvi. pp. 35-38.

† *American Journal of Science*, vol. xlv. pp. 464-468.

‡ *Journal of Analytical and Applied Chemistry*, vol. vi. pp. 150-152.



a case in which some steel plates delivered to an Austrian railway company, to be laid below the rails, were found to rust with extreme rapidity. An analysis was made of the rust, and it was found to contain :—

|                               | Per Cent. |
|-------------------------------|-----------|
| Water . . . . .               | 2·72      |
| Ferrous oxide . . . . .       | 9·52      |
| Ferric oxide . . . . .        | 81·69     |
| Combined carbon . . . . .     | 0·68      |
| Graphite . . . . .            | 0·10      |
| Sulphur . . . . .             | 0·51      |
| Sulphuric anhydride . . . . . | 0·24      |
| Carbonic anhydride . . . . .  | 0·70      |
| Manganese oxide . . . . .     | 0·57      |
| Lime . . . . .                | 1·23      |
| Phosphorus . . . . .          | 0·05      |
| Silica . . . . .              | 1·65      |
| Zinc . . . . .                | traces    |
| Total . . . . .               | 99·66     |

The metal itself contained—

| Fe.   | Graphite. | Combined Carbon. | Mn.  | Si.  | S.   | P.   | Ca + Mg. |
|-------|-----------|------------------|------|------|------|------|----------|
| 98·43 | 0·08      | 0·33             | 0·20 | 0·14 | 1·08 | 0·04 | traces   |

From these analyses it follows that the formation of the rust was due to the very large percentage of sulphur that was present in the metal.

**Iron Rust with Magnetic Properties.**—As a specimen of rust from some old tram-rails was found to possess magnetic properties, Professor A. Liversidge \* investigated the character of a large number of samples, and found that a very large percentage of the mass in each case was attracted by the magnet. Precautions were taken to prevent metallic iron being present. The conclusions drawn from these experiments, and from some others on the occurrence of magnetite in certain ores and rocks, are, that native ferric oxide and its hydrates, such as hæmatite, limonite, goethite, &c., are themselves non-magnetic, but may contain some magnetite. Sesquioxide of iron obtained by precipitation from the acid carbonate is magnetic, or may be rendered so by long boiling, or by heating at various temperatures up to redness, and it is free from monoxide. Magnetic sesquioxide free from the monoxide can be obtained by heating the magnetic oxide. Ordinary rust produced by oxidation of iron is usually magnetic, and

\* *Transactions of the Australasian Association for the Advancement of Science*, 1892; *Iron*, vol. xl. pp. 492 and 558.



the whole of the combined carbon passes into the gas evolved on the solution of the metal. Further, that the portion of the carbon which passes away as a hydrocarbon is not proportional to the percentage of combined carbon contained in the metal; that none of the numerous varieties of iron and steel examined gave off either the whole or any definite proportion of the carbon they contained as hydrocarbon, although the total percentage of carbon in the samples varied within the very wide limits of less than 0·2 to as much as 6·37. Neither is the volume of the gas produced proportionate to the percentage of combined carbon contained in the metal dissolved, and the only positive results that these experiments gave were, that hydrochloric acid, when used as a solvent, gives larger volumes of gas than does sulphuric acid, the gas being also richer in carbon; that, as a rule, a larger volume of gas is accompanied by a diminution in the percentage of carbon, though not a proportionate one; and, finally, that that portion of the carbon which does not escape as gas, but remains in the solution, retains in combination large quantities of hydrogen, thus diminishing the observed volume of the gas resulting from the solution. This must all depend on the way the carbon exists in the iron, and the author refers to the experiments made by different investigators in connection with this subject, and he considers that it is due to the quantity and the composition of the combined carbon—of the iron carbide, that is—which occurs in the metal, that the variations observed in the quantity and composition of the gas is due.

The quantity of hydrocarbons that is evolved is not always in strict relation to the percentage of “combined” carbon contained in the iron, as, in consequence of the heat given off when the metal is attacked with acid, the hydrocarbons evolved are usually partly decomposed with the deposition of solid carbon. There is consequently no doubt but that the solution of an iron which contains carbon is a matter involving much complicity of reaction, and that much caution is necessary when drawing conclusions as to the nature of the iron treated from the composition of the products obtained in its solution in acid. Nitric acid is a solvent whose action on iron, while energetic, yet can be followed better than that of most other solvents. Take the case of a piece of hardened steel dipped in the acid. It becomes covered with a coating of carbon. The question may be asked, whether the reaction in this case is not similar to the decomposition of a sulphide by nitric acid? It leads to the conclusion that the carbon does not exist in the iron simply as a dissolved material, but that it is in some state of combination which the nitric acid can decompose, a true chemical compound—a carbide,



although the actual composition of this carbide is still a matter of doubt. The oxidation of the hydrogen which is evolved at the same time as the carbon does not simply lead to the formation of water, but it also leads to the hydration of the liberated carbon, the OH of the OH - H group combining with carbon, the hydrogen finding for itself a new molecule of oxygen. It follows that the solution of iron is not effected, as has been thought, without the evolution of nascent hydrogen, but that this hydrogen combines with the deposited carbon, and it is to this that is due the formation of the hydrocarbides, which are obtained as a residue when iron containing carbon is dissolved by such salts as chlorides or sulphates, or by the electric current. The author is of opinion that the changes observed by Osmond are in reality due to a rearrangement of the atoms within the molecules of the iron carbide present. He considers that the molecules undergo a change analogous to that of other organic carbides, larger and more complex molecules being produced as the temperature of the metal rises, and simpler and smaller molecules as the temperature falls. Even small alterations of temperature should suffice to bring about such molecular changes.

# CHEMICAL ANALYSIS.

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### I.—ANALYSIS OF IRON AND STEEL.

**The Analysis of Iron and Steel.**—The causes of discrepancy in chemical analysis are discussed by Dr. C. B. Dudley,\* with special reference to the determination of carbon, sulphur, and other constituents in iron and steel. There are four main causes of error to which discrepancies may be attributed. These are—(1) the sample may not be the same; (2) the degree of purity of the chemicals varies; (3) the personal error in manipulation; (4) the use of different methods. As regards the first cause, the author has not had much trouble, though in one case he cites the fact that samples taken from the exterior and from the core of some steel springs gave different percentages of carbon. The second cause is familiar to every one. There are two ways of counteracting its effects: either the chemicals should be tested, or a blind test made. The first is not always feasible, and even the second is far from satisfactory, as the reactions may vary owing to the absence of the elements in the sample. The third cause, that of personal error, introduces discrepancies through difference of manipulation. This often arises from the indefinite nature of the instructions, or from the inaccuracy in the amount of reagents used, or of the time employed. In one case, an interval of two days in the determination of silicon in steel by Brown's method caused the result to be just half of what it should have been. The fourth cause is one that can be easily eliminated, and the author proposes that in every specification the test shall be included. This the author is endeavour-

\* Paper read before the Engineers' Society of Western Pennsylvania, Chemical Section, September 27, 1892.







The ammonium molybdate solution is obtained by dissolving 1 lb. of molybdic acid in 1200 cubic centimetres of water, stirring in 700 cubic centimetres of ammonia of 0.90 specific gravity, and mixing with 300 cubic centimetres of nitric acid of 1.42 specific gravity. Every 550 cubic centimetres of this solution is added to 500 cubic centimetres of 1.42 nitric acid, and 1200 cubic centimetres of water. The caustic soda solution is obtained by dissolving 15.4 grammes of caustic soda in 100 cubic centimetres of water, and adding a saturated solution of barium hydrate until no more precipitate is formed, filtering rapidly, and diluting to 2 litres. The nitric acid solution is made of the same standard as the soda solution. One gramme of pure ammonium phosphomolybdate is used in standardising. If the standard solutions are either too strong or too weak, they are diluted or strengthened to whatever extent is required to make 1 cubic centimetre equivalent to 0.0002 gramme of phosphorus.

N. von Lorenz \* discusses the sources of error in the determination of phosphoric acid by magnesia mixture. These mainly consist in the precipitation of magnesia with the phosphorus precipitate. This can be avoided by the addition of 2 per cent. of ammonium citrate before the precipitation with magnesia mixture, no magnesia being then precipitated. The magnesia mixture should be added drop by drop, except when much citrate is present.

Messrs. W. Macfarlane and A. Wilson † describe the methods used for the determination of phosphorus by the Glengarnock Iron and Steel Company. By the standard method, 2 grammes of the metal are dissolved in 15 cubic centimetres each of nitric and hydrochloric acid. The solution is evaporated to dryness, allowed to stand on the hot plate for ten minutes, cooled, and the residue taken up with hydrochloric acid and then boiling water. After filtration, the solution is neutralised with ammonia, and the iron reduced by ammonium bisulphite. Excess of sulphurous anhydride is boiled off, ferric chloride sufficient to combine with the phosphorus is added, and ferric phosphate is precipitated by ammonium carbonate. The precipitate is dissolved off the filter by hot dilute hydrochloric acid, neutralised with ammonia and nitric acid, and 200 cubic centimetres of molybdate solution is added to the solution at 85° C. The precipitate is filtered off, dissolved in ammonia, neutralised with hydrochloric acid, and the phosphorus precipitated by magnesia mixture and ammonia. The precipitate is dried, ignited, and weighed.

For the rapid method, a fractional portion of the solution is taken,

\* *Zeitschrift für Analytische Chemie*, vol. xxxii. p. 64.

† Paper read before the West of Scotland Iron and Steel Institute, January 1893.









sulphur, but less than when cold acid was used, and the best results were always below those obtained from solution in aqua regia with fusion of the first precipitate of barium sulphate with sodium carbonate.

A series of experimental determinations of sulphur in a sample of pig iron has been instituted by the Crane Iron Company, the analyses having been made by various chemists of repute in the United States and in Germany. The results obtained varied between 0·005 and 0·024 per cent., as shown in the following table : \*—

| Method.                                                                                                                                                | Percentage Found. |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|
| Nitro-hydrochloric acid . . . . .                                                                                                                      | 0·006             |
| Absorption and oxidation with bromine, and weighing the insoluble residue as barium sulphate . . . . .                                                 | 0·008             |
| Absorption and titration with a standard solution of iodine . . . . .                                                                                  | 0·009             |
| Absorption in an alkaline solution of lead nitrate, and weighing as barium sulphate . . . . .                                                          | 0·011             |
| Nitro-hydrochloric acid method, allowing the solution to settle for twenty-four hours . . . . .                                                        | 0·012             |
| Nitro-hydrochloric acid . . . . .                                                                                                                      | 0·012             |
| Absorption in potassium permanganate solution, and weighing the BaSO <sub>4</sub> precipitate . . . . .                                                | 0·013             |
| Absorption in cadmium solution, and titration with iodine . . . . .                                                                                    | 0·013             |
| Potassium permanganate method, weighing as BaSO <sub>4</sub> . . . . .                                                                                 | 0·013             |
| Nitro-hydrochloric acid method, neutralising with ammonia, precipitating as BaSO <sub>4</sub> , and allowing to settle for twenty-four hours . . . . . | 0·013             |
| Absorption in cadmium chloride solution, and titration with iodine . . . . .                                                                           | 0·015             |
| Absorption and titration with iodine . . . . .                                                                                                         | 0·015             |
| Absorption and titration with iodine . . . . .                                                                                                         | 0·017             |
| Absorption in potassium permanganate, and weighing as barium sulphate . . . . .                                                                        | 0·017             |
| Volumetric, no details given . . . . .                                                                                                                 | 0·019             |
| Absorption with cadmium sulphate, and titration with iodine . . . . .                                                                                  | 0·020             |
| Nitro-hydrochloric acid method . . . . .                                                                                                               | 0·021             |
| Absorption in caustic soda solution, and titration with iodine . . . . .                                                                               | 0·022             |
| Nitro-hydrochloric acid method . . . . .                                                                                                               | 0·024             |

It is evident from these results that no one method possessed marked advantages over the others. The greatest differences are observable in the nitro-hydrochloric acid method. Assuming that the reagents used in this method are perfectly pure, the chief causes of error are the following :—(1.) Evaporating too far before filtering off the silica and graphite, leading as this does to the formation of basic iron salts, which retain some sulphur, and are insoluble in dilute acid. (2.) The precipitation of the barium sulphate in too acid a solution. This delays the formation of the precipitate very considerably, and too low a result is probable unless the solution is allowed to stand from twelve to fourteen hours

\* *Journal of Analytical and Applied Chemistry*, vol. vi. pp. 318-320.







dryness, taken up with sulphuric acid, and diluted to 300 cubic centimetres. It is then filtered through a folded filter, 100 cubic centimetres, reduced with iron wire, neutralised with sodium carbonate, and then, to convert the iron into ferrocyanide, the solution is poured into a boiling mixture of potassium cyanide and caustic potash. The precipitate of ferric hydrate is filtered off, the filtrate diluted to 500 cubic centimetres, filtered again, and then 300 cubic centimetres are treated with ammonium nitrate in a porcelain dish, using one and a half times the weight of the salt, as compared with that of the caustic potash used with the cyanide. On heating for an hour, the alumina settles out and can be filtered, washed, and weighed.

For the determination of aluminium in steel, P. Rozycki \* places from 0·2 to 2 grammes of the iron in the form of very thin foil in a platinum boat, and heats to redness in a current of oxygen. When the oxidation is complete, the current of oxygen is replaced by one of hydrochloric acid gas. The iron is volatilised, leaving alumina and silica in the residue. This may be treated with hydrochloric acid to dissolve out the silica, and the alumina may then be ignited and weighed.

**The Determination of Nickel and Cobalt.**—The analysis of nickel and nickeliferous compounds generally is dealt with by Mr. S. H. Emmens,† the various processes being given in tabular form. According to him, none of the published methods are strictly accurate, as there is risk of nickel being carried down with the ferric hydrate, and lost in precipitation methods; neither can electrolytic methods be relied upon. The distinguishing feature of the method proposed is the boiling of the precipitated ferric hydrate with a small quantity of hydrochloric or sulphuric acid. From thermo-chemical data it is shown that the nickel will pass into solution in preference to the iron. The small amount of iron in solution is then reprecipitated by ammonia in presence of ammonium chloride, and after filtration and evaporation to small bulk, the nickel and cobalt are thrown down by sodium hydrate, and the precipitate is then dissolved in hydrochloric acid. The solution is made alkaline with ammonia, and electrolysed to determine these two metals.

M. Syssoyeff ‡ describes a gas volumetric method for the determination of nickel. This depends on the fact that  $\text{Ni}_2\text{O}_3$  and  $\text{H}_2\text{O}_2$  reduce each other according to the reaction :—



\* *Moniteur Scientifique*, 4th Series, vol. vi. p. 815.

† *Engineering and Mining Journal*, vol. liv. pp. 510-511.

‡ *Moniteur Scientifique*, 4th Series, vol. vi. p. 865.



added, and a rapid current of sulphuretted hydrogen is passed through the solution, the solution begins to become discoloured after about thirty seconds. A white precipitate forms in the first instance, which soon becomes yellow, and within an hour and a half the whole of the arsenic has been deposited as the penta-sulphide. The hydrochloric acid must be present in the quantity of at least two parts of concentrated acid to one of water, and the solution must not be heated, or else some of the arsenic will distil off. The acid should be added gradually. The author believes that in the first instance a higher chloride of arsenic is formed, and that at higher temperatures this escapes in the form of tri-chloride. The precipitate obtained in this manner is filtered into a Gooch crucible, washed with water, and then with hot alcohol. It is next dried at  $100^{\circ}$ , and then weighed. If in the original strongly acid solution antimony, bismuth, lead, or cadmium was present, it will remain in solution, but it is advisable to pass a current of air through the solution after the deposition of the arsenic to drive out the sulphuretted hydrogen before washing the precipitate with hydrochloric acid. If tin or copper is present, it passes, in part, into the arsenic precipitate.

## II.—ANALYSIS OF IRON ORE AND SLAG.

**The Determination of Iron.**—E. Nihoul\* describes a process for the estimation of iron in its ores which depends on the volumetric determination of iodine liberated from potassium iodide by ferric salts in their reduction to ferrous salts. From 0.3 to 0.5 gramme of the mineral is placed in a retort with 25 cubic centimetres of concentrated hydrochloric acid and heated. A current of gaseous hydrochloric acid is preferably passed until solution is complete. The iron is peroxidised by chlorate or potassium permanganate, and hydrochloric acid is passed into the boiling solution until chlorine ceases to be evolved. The retort is then connected to a condenser, and a slight excess of potassium iodide in solution is added, and the iodine liberated by the reduction of the ferric salts is distilled over in a current of carbonic anhydride into the condenser. From there it is collected and titrated with sodium hyposulphite. One part of iodine corresponds to 0.4416 of iron. If the iron is all present in the ferric state, the iodide may be added in the retort at first to aid solution.

\* *Revue Universelle des Mines*, vol. xxi. pp. 58-64.





separated from Zn, Ni, Co, Cu, Bi, and Ca. Lead can be best separated from Zn, Cu, and Ag from solutions which contain small quantities of nitric or acetic acid. If only one other metal, in addition to the lead, is present, this is determined by the aid of potassium ferricyanide, while in another portion of the solution both metals are precipitated by ferrocyanide. If in both cases the solutions used contain one-fortieth part of a molecule of the salt to the litre, then all that is necessary is to subtract the cubic centimetres of solution used in the first case from those used in the second, in order to determine the lead by difference. A table is given showing the precipitates produced by ferrocyanide and ferricyanide in different solutions.

**The Determination of Manganese.**—A. H. Low \* dissolves 0.5 gramme of the ore in a 16-oz. flask with from 5 to 10 cubic centimetres of hydrochloric acid or aqua regia, and boils until the free acid is nearly gone. He then dilutes with hot water and adds an excess of zinc oxide, boiling to effect the complete neutralisation of the acid. An excess of bromine solution is then added—about 25 cubic centimetres, but never more than 50 cubic centimetres—and the whole is boiled until the excess has been expelled, red fumes ceasing to appear. The precipitate is filtered through a 5-inch filter, the washed precipitate, together with the filter-paper, being treated with 50 cubic centimetres of a 10 per cent. sulphuric acid solution. Into the solution, &c., so obtained a standard solution is run from a burette. This is a solution of 11.46 grammes of oxalic acid in a litre of water, standardised by a 10 per cent. normal solution of potassium permanganate in the presence of hot dilute sulphuric acid.

An excess of the oxalic acid having been judged to have been run into the precipitate from the ore made in the manner above described, the mixture is heated to boiling, and more oxalic acid added, if necessary, to effect the complete solution of the precipitate. The whole is then diluted with hot water, and the excess of oxalic acid titrated with the standard permanganate solution. The number of cubic centimetres actually consumed by the  $\text{MnO}_2$  is thus arrived at, and the whole analysis completed in about twenty minutes. None of the ordinary constituents of ores interfere with the method. The oxalic acid used is of such a strength that 1 cubic centimetre equals about 1 per cent. of manganese.

\* *Journal of Analytical and Applied Chemistry*, vol. vi. No. 12; *Chemical News*, vol. lxxvii. p. 162.



D. Martelli,\* however, has compared Mancuso-Lima's method with the usual Italian methods and with that described by König,† and concludes that König's method is the best, as effecting a saving of time and of reagents.

Messrs. C. Arnold and K. Wedemeyer‡ discuss the method for the determination of phosphoric anhydride in basic slag described by M. Spica.§ The authors are of opinion that the method is for works' laboratories both too long and too costly, and that it is not easy to get accurate results by its aid.

### III.—FUEL ANALYSIS.

**The Analysis of Fuel.**—H. von Jüptner|| observes that, in view of the very variable composition of different portions of one and the same fuel, it is a difficult matter to obtain a small sample which shall really represent the average composition of the fuel. He therefore abandons the ordinary method, in which one-gramme samples are burnt, and adopts instead the combustion of a much larger quantity in a furnace of special design. The percentage of hygroscopic water can be determined in the ordinary way, as very large samples can be used, and since the percentage of hygroscopic water in a fuel does not vary very greatly under similar conditions. Similarly, too, the percentage of ash may either be determined as usual with small samples, or it is determined when making the combustion experiment with the larger sample. In this latter case a careful sample must be taken from the ash residues, and this must be completely incinerated, with a view to ascertain the amount of unconsumed carbon remaining in it. The loss of weight may be considered as being wholly due to carbon. That portion of the carbon which is deposited in the form of lampblack is, as a rule, so small in weight that it may be neglected, or, if it is desired to determine it, collected in the ordinary way. The only remaining portion of the fuel which requires determination is that which escapes in gaseous form—the carbon, the “disposable” hydrogen, and the so-called chemically combined water. It is easy enough to determine the ratio borne

\* *Le Stazione Speriment. Agric. Ital.*, vol. xxi. pp. 453–455.

† *Untersuchung landwirtschaftlicher und gewerbewichtiger Stoffe.* Berlin, 1891, p. 178.

‡ *Zeitschrift für angewandte Chemie*, 1892, p. 603.

§ *Journal of the Iron and Steel Institute*, 1892, No. II., p. 525.

|| *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. pp. 84–87 and 96–100.



them to be simple enough for ordinary works' routine, and to be capable of being used for exact measurements. A tube and reservoir is used for regulating the pressure, and the measuring and pressure tubes are set in a cold-water tank. A modified form of bulb, as in Hempel's apparatus, is used, and shaped so that the gas can bubble through the liquid, and the bulbs are placed horizontally. A rocking motion is given to the apparatus. Friedrich's patent stopcock is used. An illustration of the apparatus is given, and several slight modifications were proposed in the discussion.

# STATISTICS.

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### I.—UNITED KINGDOM.

**Mineral Statistics.**—According to the official report of Her Majesty's Inspector of Mines,\* the production of coal in the United Kingdom in 1892 amounted to 181,786,871 tons. The production during the previous year was 185,479,126 tons.

The total quantity of iron ore raised was 11,312,675 tons, of which 5,644,486 tons was obtained from mines under the Coal Mines Act, 2,353,706 from mines under the Metalliferous Mines Act, and 3,314,483 tons from open works. The production of manganese ore amounted to 6078 tons.

The production of pig iron in the United Kingdom in 1892 amounted to 6,709,255 tons, the production of the previous year having been 7,406,064 tons. There were 149 works in operation with 741 furnaces, of which 376 were in blast.

**Imports and Exports.**—According to the Board of Customs returns, the exports from the United Kingdom during 1892 and 1891 were as follows :—

\* *Mineral Statistics of the United Kingdom.* London, 1893.

| Description.                           | 1892.            | 1891.            |
|----------------------------------------|------------------|------------------|
|                                        | Tons.            | Tons.            |
| Pig iron . . . . .                     | 767,053          | 840,055          |
| Bar, angle, bolt, and rod . . . . .    | 173,414          | 217,121          |
| Railroad . . . . .                     | 468,003          | 702,247          |
| Wire (except telegraph wire) . . . . . | 47,350           | 67,516           |
| Tinplates . . . . .                    | 395,449          | 448,379          |
| Cast and wrought . . . . .             | 319,909          | 364,903          |
| Old iron . . . . .                     | 297,236          | 321,367          |
| Unwrought steel . . . . .              | 106,488          | 111,068          |
| Steel and iron manufactures . . . . .  | 149,131          | 150,452          |
|                                        | 15,246           | 17,038           |
| <b>Totals . . . . .</b>                | <b>2,739,279</b> | <b>3,240,146</b> |

The imports into the United Kingdom during the same years were as follows :—

| Description.                             | 1892.     | 1891.     |
|------------------------------------------|-----------|-----------|
|                                          | Tons.     | Tons.     |
| Iron ore . . . . .                       | 3,778,653 | 3,180,543 |
| Bar, angle, bolt, and rod iron . . . . . | 75,915    | 77,416    |
| Unwrought steel . . . . .                | 7,083     | 8,436     |
| Girders, beams, and pillars . . . . .    | 74,586    | 74,035    |
| Unenumerated . . . . .                   | 143,778   | 155,044   |

## II.—*AUSTRALASIA.*

**Mineral Statistics of New Zealand.**—In the report on the mining industry of New Zealand, the output of coal for 1891 is given as 668,794 tons, of coke 2544 tons, of hæmatite ore 1 ton, and of manganese ore 1153 tons.

A report by a committee appointed by the New Zealand Legislature on the New Zealand industries has recently appeared. Amongst other subjects, consideration is given to the production of iron in the Colony, and it is recommended that a bonus be given and that the tariff be raised as soon as works are sufficiently advanced. Coal deposits occur over considerable areas, and the production of this mineral is compared with that in New South Wales.

**Mineral Statistics of Tasmania.**—According to the Colonial Blue Book, the output of coal in Tasmania in 1891 amounted to 45,524 tons, valued at £1 per ton.





**Imports and Exports.**—The following table shows the Belgian iron trade imports and exports for 1892 and 1891 :—

| Description.                  | Imports.       |                | Exports.       |                |
|-------------------------------|----------------|----------------|----------------|----------------|
|                               | 1892.          | 1891.          | 1892.          | 1891.          |
|                               | Tons.          | Tons.          | Tons.          | Tons.          |
| Crude cast steel . . . . .    | 8,861          | 6,589          | 925            | 973            |
| Steel rails . . . . .         | 625            | 1,164          | 73,043         | 60,171         |
| Other steel . . . . .         | 7,778          | 4,480          | 13,710         | 17,707         |
| Wrought steel . . . . .       | 1,480          | 941            | 11,289         | 8,579          |
| Pig iron . . . . .            | 153,105        | 183,542        | 18,227         | 17,002         |
| Scrap iron . . . . .          | 24,919         | 21,939         | 9,613          | 6,962          |
| Iron wire . . . . .           | 4,796          | 5,126          | 2,260          | 2,693          |
| Iron rails . . . . .          | 66             | 266            | 15,655         | 25,804         |
| Iron plates . . . . .         | 1,367          | 1,555          | 54,522         | 47,848         |
| Iron, miscellaneous . . . . . | 12,434         | 12,395         | 203,171        | 213,641        |
| Nails . . . . .               | 689            | 738            | 7,001          | 9,606          |
| Wrought iron . . . . .        | 3,638          | 3,792          | 31,226         | 31,003         |
| Castings . . . . .            | 1,312          | 1,413          | 23,780         | 29,146         |
| Rolling stock . . . . .       | 1,458          | 2,193          | 41,288         | 45,601         |
| Machinery . . . . .           | 14,813         | 15,973         | 36,889         | 38,817         |
| <b>Totals . . . . .</b>       | <b>237,341</b> | <b>262,106</b> | <b>542,599</b> | <b>555,553</b> |

The imports of iron ore during 1892 were 1,681,074 tons, against 1,534,276 tons in 1891; the exports 225,029 tons, compared with 192,127 tons.

The imports and exports of coal and coke were as follows :—

| Description.      | Coal.     |           | Coke.   |         |
|-------------------|-----------|-----------|---------|---------|
|                   | 1892.     | 1891.     | 1892.   | 1891.   |
|                   | Tons.     | Tons.     | Tons.   | Tons.   |
| Imports . . . . . | 1,486,667 | 1,621,065 | 191,173 | 140,576 |
| Exports . . . . . | 4,538,118 | 4,750,232 | 955,028 | 933,668 |

## V.—CANADA.

**Mineral Statistics.**—The statistics of mineral production in the dominion of Canada for 1892 are not all yet available.\* Mr. E. Gilpin reports that in Nova Scotia the production in 1892 was as follows :—

\* *The Mineral Industry*, New York, 1893, p. 518.

|                         |           |
|-------------------------|-----------|
|                         | Tons.     |
| Coal . . . . .          | 1,942,000 |
| Iron ore . . . . .      | 75,000    |
| Manganese ore . . . . . | 111       |

In Ontario, the production, according to Mr. A. Blue, included 800,000 barrels of petroleum, 2082 tons of nickel ore, and 160,000 dollars' worth of natural gas.

In Quebec, the production of iron ore is given by Mr. J. Obalski at 28,090 tons.

In British Columbia the production of coal, according to Mr. A. Dick, was 826,335 tons, of which 64,579 tons was exported.

The coal production of Alberta or the North-West Territory is estimated to have been 351,338 tons.

**Iron Trade Imports.**—The imports of iron into Canada are given as follows for 1892 : \*—

|                                |        |
|--------------------------------|--------|
|                                | Tons.  |
| Wrought iron scrap . . . . .   | 36,543 |
| Pig iron . . . . .             | 68,918 |
| Blooms, muck iron, &c. . . . . | 3,100  |
| Bar iron . . . . .             | 7,500  |

VI.—FRANCE.

**Iron and Steel.**—The production of pig iron for 1892 is stated to have been as follows :—

| Description.                | Forge Pig Iron. | Foundry Pig Iron. |
|-----------------------------|-----------------|-------------------|
|                             | Metric Tons.    | Metric Tons.      |
| Coke pig iron . . . . .     | 1,602,417       | 395,424           |
| Charcoal pig iron . . . . . | 10,519          | 1,774             |
| Mixed brands . . . . .      | ...             | 12,855            |
| Totals . . . . .            | 1,612,936       | 410,053           |
| Totals in 1891 . . . . .    | 1,497,751       | 421,434           |
| Increase . . . . .          | 115,185         | ...               |
| Decrease . . . . .          | ...             | 11,381            |

The total production of pig iron thus amounted to 2,022,989 metric tons, against 1,919,185 tons in 1891.

\* *Canadian Manufacturer ; Engineering and Mining Journal*, vol. lv. p. 317 ; *American Manufacturer*, vol. lii. p. 633.

The production of manufactured iron was as follows :—

| Description.                        | 1892.        | 1891.        |
|-------------------------------------|--------------|--------------|
|                                     | Metric Tons. | Metric Tons. |
| Puddled rails . . . . .             | 418          | 514          |
| Merchant iron, puddled . . . . .    | 575,640      | 560,703      |
| „ „ charcoal . . . . .              | 10,542       | 11,909       |
| „ „ obtained by reheating . . . . . | 120,010      | 124,187      |
| Total merchant iron . . . . .       | 706,192      | 696,799      |
| Plates, puddled . . . . .           | 112,086      | 102,964      |
| „ charcoal . . . . .                | 2,019        | 2,503        |
| „ by reheating . . . . .            | 7,453        | 8,841        |
| Total plates . . . . .              | 121,558      | 114,308      |
| Total production . . . . .          | 828,168      | 811,621      |

The production of steel was as follows :—

| Description.                      | 1892.        | 1891.        |
|-----------------------------------|--------------|--------------|
|                                   | Metric Tons. | Metric Tons. |
| Cast steel—                       |              |              |
| Rails . . . . .                   | 231,484      | 194,162      |
| Bars, blooms, &c. . . . .         | 282,707      | 272,656      |
| Plates . . . . .                  | 116,504      | 111,754      |
| Various steels—                   |              |              |
| Puddled or forged steel . . . . . | 12,135       | 14,332       |
| Cement steel . . . . .            | 1,295        | 1,398        |
| Crucible steel . . . . .          | 10,861       | 10,165       |
| Totals . . . . .                  | 655,086      | 604,467      |
| Summary —                         |              |              |
| Bars . . . . .                    | 307,098      | 298,551      |
| Rails . . . . .                   | 231,484      | 194,162      |
| Plates . . . . .                  | 116,504      | 111,754      |
| Totals . . . . .                  | 655,086      | 604,467      |

**Imports and Exports.**—The French iron trade imports and exports during the years 1892 and 1891 were as follows : \*—

\* *Moniteur des Intérêts Matériels*, vol. xliii. p. 333.

| Description.                  | Imports   |           | Exports. |         |
|-------------------------------|-----------|-----------|----------|---------|
|                               | 1892.     | 1891.     | 1892.    | 1891.   |
|                               | Tons.     | Tons.     | Tons.    | Tons.   |
| Coke . . . . .                | 1,424,203 | 1,319,827 | 55,711   | 58,421  |
| Iron ore . . . . .            | 1,683,758 | 1,437,536 | 304,646  | 298,550 |
| Crude iron of all classes . . | 87,273    | 56,756    | 120,755  | 98,058  |
| Manufactured iron . . . .     | 17,912    | 13,174    | 30,010   | 34,116  |
| Steel . . . . .               | 5,255     | 5,303     | 9,001    | 18,079  |
| Totals of iron and steel .    | 110,440   | 75,233    | 159,766  | 150,253 |

Of iron and steel imported and exported after manufacture, the quantities were as follows :—

| Description.              | Imports. |         | Re-exports. |         |
|---------------------------|----------|---------|-------------|---------|
|                           | 1892.    | 1891.   | 1892.       | 1891.   |
|                           | Tons.    | Tons.   | Tons.       | Tons.   |
| Pig iron :—Forge . . . .  | 28,654   | 55,186  | 24,992      | 56,350  |
| Foundry . . . .           | 34,051   | 78,350  | 31,298      | 40,901  |
| Manufactured iron . . . . | 21,717   | 18,688  | 23,445      | 17,861  |
| Steel . . . . .           | 1,679    | 2,480   | 2,249       | 2,326   |
| Totals . . . . .          | 86,101   | 154,704 | 81,984      | 117,438 |

The French imports and exports of coal and coke for the year 1892, as compared with the previous year, were as follows :—

| Description.   | Imports.  |           | Exports. |         |
|----------------|-----------|-----------|----------|---------|
|                | 1892.     | 1891.     | 1892.    | 1891.   |
|                | Tons.     | Tons.     | Tons.    | Tons.   |
| Coal . . . . . | 9,082,506 | 9,222,073 | 829,500  | 820,482 |
| Coke . . . . . | 1,292,453 | 1,319,827 | 75,329   | 58,421  |

**The Iron Ore Deposits of Algiers.**—According to the French official returns,\* there are two important deposits of iron ore in Algiers. One of these, in the department of Constantine, consists of magnetite,

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xli. p. 11.

whilst the other, in the department of Oran, consists of a red hæmatite rich in manganese. The chief company working these two deposits is that of Mokta-el-Hadid. This company mined in 1890, from their mines at Beni Saf, in Oran, 345,000 tons of hæmatite of an average value of 7s. 1½d. per ton, whilst the value of each of the 129,000 tons of magnetite raised at the Aïn-Mokra mines, Constantine, was 6s. 9d. Altogether there was raised in Algiers in 1890, 475,000 tons of ore, the quantity exported during the same year being 517,000 tons. The ore raised exceeded that named in the previous year by as much as 123,000 tons, and the quantity exported showed a similar increase of 78,000 tons.

VII.—GERMANY.

**Iron Trade Statistics.**—The official statistical returns show that the production of iron ore, iron, and steel in Germany and Luxemburg was as follows in the years mentioned : \*—

| Description.                                                     | 1889.      | 1890.      | 1891.      |
|------------------------------------------------------------------|------------|------------|------------|
| Iron ore, tons . . . . .                                         | 11,002,187 | 11,406,132 | 10,657,522 |
| Number of productive mines . . . . .                             | 720        | 755        | 681        |
| „ workpeople employed . . . . .                                  | 37,762     | 38,837     | 35,390     |
| „ ironworks . . . . .                                            | 108        | 108        | 109        |
| Charcoal pig iron, tons . . . . .                                | 24,927     | 24,142     | 25,548     |
| Coke and mixed fuel pig iron, tons . . . . .                     | 4,499,631  | 4,634,310  | 4,615,619  |
| Workpeople employed . . . . .                                    | 23,985     | 24,846     | 24,773     |
| Total blast-furnaces . . . . .                                   | 264        | 268        | 270        |
| Active blast-furnaces . . . . .                                  | 213        | 222        | 218        |
| Foundry pig iron, tons . . . . .                                 | 610,893    | 619,008    | 702,984    |
| Acid and basic Bessemer pig iron, tons . . . . .                 | 1,965,395  | 2,135,799  | 2,337,199  |
| Forge pig iron, tons . . . . .                                   | 1,905,311  | 1,862,895  | 1,553,835  |
| Direct castings, tons . . . . .                                  | 29,295     | 32,812     | 36,964     |
| Other pig iron castings, tons . . . . .                          | 989,621    | 1,027,384  | 1,028,387  |
| Active foundries . . . . .                                       | 1,119      | 1,148      | 1,160      |
| Workpeople . . . . .                                             | 59,437     | 63,960     | 62,740     |
| “ Weld iron ” works . . . . .                                    | 261        | 255        | 250        |
| Weld iron and steel manufactures }<br>and blooms, tons . . . . . | 1,749,962  | 1,559,063  | 1,484,064  |
| “ Ingot iron ” works . . . . .                                   | 111        | 115        | 117        |
| Ingot iron manufactures and ingots, tons . . . . .               | 2,095,479  | 2,232,099  | 2,562,549  |
| Workpeople . . . . .                                             | 48,371     | 52,823     | 57,929     |
| Average value per ton of ingot metal }<br>products . . . . .     | £6 13 6    | £7 7 4     | £6 11 7    |

The quantity of rails made amounted to 427,899 tons in 1889, 559,746 tons in 1890, and 596,209 tons in 1891. Of wire 183,311

\* *Stahl und Eisen*, vol. xiii. pp. 32-34.

tons was made in 1889, 217,264 tons in 1890, and 277,800 tons in 1891. Indeed nearly every ingot metal manufacture shows a marked increase in the period under review.

**Production of Pig Iron.**—The production of pig iron in Germany during the year 1892 amounted to 4,793,003 tons, as compared with 4,452,019 tons in 1891. This output was composed as follows : \* —

| Description.                              | Metric Tons. | Per Cent. of Total Quantity. |       |
|-------------------------------------------|--------------|------------------------------|-------|
|                                           |              | 1892.                        | 1891. |
| Forge pig iron and spiegeleisen . . . . . | 1,842,167    | 38·4                         | 39·2  |
| Acid Bessemer pig iron . . . . .          | 313,819      | 6·6                          | 8·7   |
| Basic pig iron . . . . .                  | 2,006,400    | 41·8                         | 38·3  |
| Foundry pig iron . . . . .                | 630,617      | 13·2                         | 13·8  |
| Totals . . . . .                          | 4,793,003    | 100·0                        | 100·0 |

These statistics are those collected by the German Iron and Steel Association. The official Government returns give the output of pig iron in 1891 as 4,641,217 tons. The official statistics for 1892 have not appeared.

**Imports and Exports.**—The iron trade imports into Germany were as follows in the years mentioned : †—

| Description.                               | 1891.        | 1892.        |
|--------------------------------------------|--------------|--------------|
|                                            | Metric Tons. | Metric Tons. |
| Pig iron . . . . .                         | 244,852      | 209,306      |
| Scrap . . . . .                            | 5,164        | 6,419        |
| Shaped iron . . . . .                      | 724          | 281          |
| Rails . . . . .                            | 15,773       | 7,186        |
| Bar iron . . . . .                         | 22,364       | 21,085       |
| Blooms and ingots . . . . .                | 654          | 440          |
| Sheets and plates . . . . .                | 2,711        | 2,632        |
| Total iron and iron manufactures . . . . . | 329,396      | 278,457      |
| Iron ore . . . . .                         | 1,408,025    | 1,655,843    |

The iron trade exports from Germany in the year 1892 were as follows, those for 1891 being also shown : ‡—

\* *Stahl und Eisen*, vol. xiii. p. 128.

† *Ibid.*, vol. xiii. p. 214.

‡ *Ibid.*, vol. xiii. p. 180.

| Description.                               | 1892.        | 1891.        |
|--------------------------------------------|--------------|--------------|
|                                            | Metric Tons. | Metric Tons. |
| Pig iron . . . . .                         | 113,391      | 64,377       |
| Scrap . . . . .                            | 64,627       | 59,465       |
| Angle iron . . . . .                       | 84,055       | 74,631       |
| Rails . . . . .                            | 113,712      | 142,846      |
| Sleepers, &c. . . . .                      | 39,558       | 63,406       |
| Bar iron . . . . .                         | 199,064      | 193,253      |
| Blooms and ingots . . . . .                | 37,184       | 42,458       |
| Wire . . . . .                             | 187,376      | 167,471      |
| Plates and sheets . . . . .                | 58,377       | 64,575       |
| Total iron and iron manufactures . . . . . | 1,133,676    | 1,166,043    |
| Total iron ores . . . . .                  | 2,276,155    | 1,984,428    |

The total value of the iron and iron manufactures exported in 1892 amounted to £13,334,450, a total differing by less than £3 from that of the previous year. The value of the iron ore exported in 1892 was £352,800, as compared with £305,200, the value of the ore exported in 1891.

**Production of Iron in Saxony.**—In the year 1891 pig iron was made at only one works in Saxony, the Königin Marien Works at Cainsdorf. Its production was as follows in the years mentioned :—

| Description.                | 1891.      | 1890.      |
|-----------------------------|------------|------------|
|                             | Tons.      | Tons.      |
| Foundry pig iron . . . . .  | 13,774,995 | 6,879,985  |
| Forge pig iron . . . . .    | 7,693,820  | 5,581,700  |
| Bessemer pig iron . . . . . | ...        | 4,693,605  |
| Castings . . . . .          | 147,720    | 112,485    |
| Totals . . . . .            | 21,616,535 | 17,267,775 |

In 1891, 150 male and 18 female workpeople were employed, and 50,109 tons of ores smelted, together with 15,797 tons of flux.\*

## VIII.—INDIA.

**Mineral Statistics.**—According to the Return of Mineral Production in India for 1891, the total yield of coal for that year amounted to 2,328,577 tons, valued at £527,610. The production of iron ore was 33,335 tons, valued at £12,865, and that of petroleum 6,136,495 gallons, valued at £31,794.

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 640.



IX.—*ITALY*.

**Mineral Statistics.**—According to the official returns,\* the production of minerals in Italy in 1891 was as follows:—

| Description.               | Production. | Number of Mines. | Number of Workmen. |
|----------------------------|-------------|------------------|--------------------|
|                            | Tons.       |                  |                    |
| Iron ore . . . . .         | 216,486     | 43               | 2,269              |
| Manganese ore . . . . .    | 2,429       | 5                | 127                |
| Coal and lignite . . . . . | 289,286     | 39               | 2,386              |
| Asphalt . . . . .          | 28,180      | 10               | 719                |
| Petroleum . . . . .        | 1,155       | 10               | 251                |
| Graphite . . . . .         | 2,415       | 12               | 67                 |

During the same year the Italian iron and steel works produced the following amounts:—

| Description.             | Production. | Number of Works. | Number of Workmen. |
|--------------------------|-------------|------------------|--------------------|
|                          | Tons.       |                  |                    |
| Pig iron . . . . .       | 11,930      | 8                | 211                |
| Malleable iron . . . . . | 152,668     | } 324            | 11,395             |
| Steel . . . . .          | 75,925      |                  |                    |

X.—*JAPAN*.

**Mineral Statistics.**—The mineral production of Japan in 1890 is stated † to include:—

|                             |              |
|-----------------------------|--------------|
|                             | Metric Tons. |
| Coal . . . . .              | 2,608,285    |
| Manganese ore . . . . .     | 2,571        |
| Graphite . . . . .          | 4,529        |
| Pig iron . . . . .          | 16,176       |
| Manufactured iron . . . . . | 4,887        |
| Steel . . . . .             | 1,173        |

The production of petroleum amounted to 2,017,116 gallons.

XI.—*RUSSIA*.

**Mineral Statistics.**—According to the statistics published by S. N. Kulibin,‡ the production of iron ore in Russia in 1890 amounted

\* *Statistica Mineraria del Regno d'Italia per l'Anno 1891.* Rome, 1892.

† *The Mineral Industry*, New York, 1893, p. 536.

‡ *Berg- und Hüttenmännische Zeitung*, vol. lii. pp. 83–85.

to 109,622,052 poods (1,769,000 tons), an increase of 9,500,000 poods as compared with 1889. Most of the ore (56,000,000 poods) was obtained from mines in the Ural. The ore was smelted at 146 ironworks with 214 blast-furnaces. The ore smelted amounted to 103,332,243 poods, with some 7,500,000 poods of slags. The yield was as follows :—

| Fuel Used.           | Poods.     | Per Cent. |
|----------------------|------------|-----------|
| Charcoal . . . . .   | 37,326,643 | 65·99     |
| Coal . . . . .       | 18,278,381 | 32·32     |
| Mixed fuel . . . . . | 955,050    | 1·96      |
| Totals . . . . .     | 56,560,074 | 100·00    |

The mean annual out-turn of a furnace was 264,299 poods (4260 tons). The production of weld iron amounted to 26,445,545 poods, or 329,166 poods more than that of the previous year. There were 172 works at which weld iron was produced.

Steel was produced at 32 works, the out-turn amounting to 23,102,797 poods, or 73,070,045 poods more than that of the previous year.

Manganese ore was raised at 300 mines, the production amounting to 11,139,701 poods, or 6,500,000 poods more than in the previous year.

There were 336 collieries producing, the output being as follows :

|                           | Poods.      |
|---------------------------|-------------|
| Bituminous coal . . . . . | 321,849,785 |
| Anthracite . . . . .      | 36,483,528  |
| Lignite . . . . .         | 8,870,732   |
| Total . . . . .           | 367,204,045 |

The production of coke amounted to 18,066,678 poods. The production of petroleum was 240,380,924 poods, that of asphalt 743,237 poods, and that of graphite 1000 poods.

**Petroleum Industry of the Caucasus.**—The most important oil-wells occur in the vicinity of the village of Balachanu, about 16 miles from Baku, in a bare plateau 100 feet above the level of the Caspian Sea. At the present time there are upwards of 1000 oil-wells producing, the output being 400,000 poods (6430 tons) per twenty-four hours. The rapid development of the industry, since the Paris house of Rothschild began to participate in the trade in 1887, is shown by the following statistics :—

| Year.          | Raw Naphtha. | Petroleum. |
|----------------|--------------|------------|
|                | Poods.       | Poods.     |
| 1887 . . . . . | 165,000,000  | 44,000,000 |
| 1891 . . . . . | 289,575,400  | 72,885,331 |

The consumption of Caucasian petroleum in 1890 amounted to 37,485,000 poods, of which 7,870,000 poods were exported to Great Britain.\*

**The Russian Iron Industry.**—The imports of iron and iron manufactures into Russia have considerably fallen in recent years, owing to the great increase which has taken place in the home industry. The quantity of iron ore raised has been as follows in the years mentioned :—

| Year.          | In all Russia. | In Russian Poland. |
|----------------|----------------|--------------------|
|                | Tons.          | Tons.              |
| 1880 . . . . . | 448,400        | 39,120             |
| 1887 . . . . . | 612,430        | 60,900             |
| 1889 . . . . . | 740,050        | 88,140             |
| 1891 . . . . . | 953,560        | 121,900            |

The quantity of iron made from this ore was as follows :—

| Year.          | In all Russia. | In Russian Poland. |
|----------------|----------------|--------------------|
|                | Tons.          | Tons.              |
| 1880 . . . . . | 284,700        | 19,710             |
| 1884 . . . . . | 362,230        | 57,310             |
| 1889 . . . . . | 427,780        | 66,356             |
| 1891 . . . . . | ...            | 72,285             |

The Ural, Russian Poland, and the south and south-western districts of Russia are the greatest centres of the iron trade. The production of malleable iron in Russia in 1880 was 17,831,000 poods, and in 1889 26,116,000. Full details are not given for the year 1890, but the production will probably exceed that of 1889, though not to any very large extent. The out-turn of steel increased from 18,761,000 poods in 1880 to 22,701,000 poods in 1890. In the previous year the out-turn had fallen to only 15,796,000 poods.

This rapid increase was mainly due to the iron and steel works of Southern Russia, and to the great increase in the demand for rails by

\* *Berg- und Hüttenmännische Zeitung*, vol. lii. pp. 61–62.

the Russian railways. Of the various varieties of steel the production of Russia was as follows in 1890 :—

|                             | Poods.     |
|-----------------------------|------------|
| Cement steel . . . . .      | 107,888    |
| Puddled steel . . . . .     | 223,185    |
| Bessemer steel . . . . .    | 4,863,780  |
| Open-hearth steel . . . . . | 10,298,453 |
| Crucible steel . . . . .    | 302,446    |

No details are available as to the production of steel rails in either 1890 or 1891, but the manufacture has been a rapidly increasing one, and the total quantity made in 1889 was 5,394,338 poods.

The imports of foreign pig iron into Russia have steadily diminished since 1883, the year in which the increased duty was established.\*

**The Coal Industry of Russia.**—Considerable progress has of late been made in the coal industry of Russian Poland. Nearly the whole of the coal raised in Russia comes either from this district or from the Donez basin, and the total output has increased from 3,493,510 tons in 1881, to as much as 6,028,110 tons in 1890. In Russian Poland the output has nearly doubled during this interval. The seventeen collieries of the Dabrowa basin in 1891 possessed 173 steam-engines of 10,946 h.p., and they gave employment to 3238 miners, and 8056 other workpeople. The imports of British coal into Odessa in 1889 were 14,828,400 poods, but by 1891 these had fallen to less than half the quantity, 7,052,703 poods, or 113,753 tons. The imports of coal and of coke into Russia in 1891 were respectively 93,837,000 poods and 12,291,000. poods. The exports of coal in the same year were 683,000 poods.†

The output of coal in Poland in 1892 amounted to 2,806,528 tons, an amount that exceeded the production of the previous year by 272,061 tons, or 10·8 per cent. Of the total amount, 80 per cent. was produced by four coal-mining enterprises. The output is expected to increase this year.‡

## XII.—SPAIN.

**Mineral Statistics.**—The following statistics relating to the mineral production of Spain are given by Román Oriol :§—

\* *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xl. p. 569.

† *Ibid.*

‡ *Industries*, vol. xiv. p. 267.

§ *Revista Minera*, vol. xlv. p. 1.

| Description.       | 1892.        | 1891.        |
|--------------------|--------------|--------------|
|                    | Metric Tons. | Metric Tons. |
| Coal . . . . .     | 1,353,860    | 1,290,464    |
| Lignite . . . . .  | 38,290       | 30,116       |
| Iron ore . . . . . | 5,436,150    | 4,822,089    |

The production of iron and steel is given as follows :—

| Description.                  | 1892.        | 1891.        |
|-------------------------------|--------------|--------------|
|                               | Metric Tons. | Metric Tons. |
| Pig iron . . . . .            | 211,436      | 278,462      |
| Wrought iron . . . . .        | 83,181       | 59,910       |
| Steel . . . . .               | 54,915       | 69,892       |
| Manufactured iron and steel . | 85,800       | 104,800      |

**Iron Trade Imports and Exports.**—The iron trade imports into Spain during the year 1892 were as follows : \*—

|                             |              |
|-----------------------------|--------------|
|                             | Metric Tons. |
| Coal . . . . .              | 1,688,537    |
| Coke . . . . .              | 175,872      |
| Briquettes, &c. . . . .     | 25,682       |
| Raw petroleum . . . . .     | 44,656       |
| Pig iron . . . . .          | 30,022       |
| Manufactured iron . . . . . | 10,177       |
| Forged steel . . . . .      | 31,637       |

The exports included—

|                         |              |
|-------------------------|--------------|
|                         | Metric Tons. |
| Iron ore . . . . .      | 4,773,827    |
| Manganese ore . . . . . | 10,410       |
| Coal . . . . .          | 14,390       |
| Pig iron . . . . .      | 43,412       |

**Exports of Iron Ore from Bilbao.**—Notwithstanding the depression of trade in other districts, the exports of iron ore were considerably greater in 1892 than in the previous year.† The quantity exported in 1892 was as follows :—

|                           |              |
|---------------------------|--------------|
| To                        | Metric Tons. |
| United Kingdom . . . . .  | 2,650,753    |
| Germany . . . . .         | 766,302      |
| France . . . . .          | 390,319      |
| Belgium . . . . .         | 75,249       |
| United States . . . . .   | 34,164       |
| Other countries . . . . . | 1,757        |
|                           | 3,918,544    |

\* *Revista Minera*, vol. xliv. p. 78.  
† *Comité des Forges de France*, Bulletin No. 718.

XIII.—*SWEDEN.*

**Mineral Statistics.**—According to the official statistics \* there was mined in 1891 in Sweden 985,255 tons of iron ore, and 2150 tons of lake and bog iron ore was also raised. The respective totals for the preceding year were 940,429 tons and 812 tons. The quantity of pig iron made amounted to 486,680 tons, and of direct castings 4233 tons, as compared with 451,443 tons, and 4660 tons respectively in 1890. In the foundries the castings made amounted to 37,515 tons, an increase of 545 tons on the out-turn of the previous year. The blooms made weighed 224,651 tons, bar iron 280,430 tons, and Bessemer metal 92,985 tons, each of these showing a diminution in the production of about a thousand tons when compared with that of the previous year. On the other hand, there was an increase of over 5000 tons in the out-turn of open-hearth metal, which reached 78,197 tons in the year under mention. Other kinds of steel made weighed only 1592 tons, as compared with 2056 tons in 1890, and iron and steel manufactures 72,438 tons, as compared with 78,998 tons. The nickel ore raised amounted to 483 tons, and the manganese ore to 9080 tons, both showing considerable reductions when compared with the respective outputs in 1890. The graphite raised weighed 16½ tons.

The production of coal amounted to 2,475,412 hectolitres in 1891, as compared with 2,343,895 in the previous year, and that of fireclay to 1,045,541 hectolitres in 1891, and 978,355 in 1890.

The active blast-furnaces numbered 155, and these were in blast 40,099 days, the average daily out-turn being 12,243 tons. In 1890, 154 furnaces were in blast, their average daily out-turn being slightly less than in 1890, 12·037 tons. The manufacture of iron castings was carried on at 133 works. Blooms and bar iron were made at 165 works, which possessed 489 hearths and other furnaces, the numbers for 1890 being respectively 157 and 445.

The Bessemer works numbered fifteen, while twenty-two works made open-hearth metal. Other kinds of steel were made at eight works. Iron and steel manufactures were made at 145 works. Of the various products, the wire made amounted to 6600 tons.

The most important works were those of Kopparberg, where 21,744 tons of manufactured articles was made. Not one of the other twenty Government works made one-half the quantity that was made at the Kopparberg Works. Scythe-blades were made at these latter works

\* *Stahl und Eisen*, vol. xii. p. 1007.



The total production of Bessemer steel ingots in 1890, the year of largest production prior to 1892, was 3,688,871 tons, which was 472,101 tons less than in 1892.

The total production of Bessemer steel rails in 1892, with the exception of the small quantity of rails made by other manufacturers from purchased materials, was 1,458,743 tons, an increase of 219,350 tons over the production in 1891. The following table shows the production in 1892 compared with that of 1891 :—

*Rails.*

| States.                | 1892.     | 1891.     |
|------------------------|-----------|-----------|
|                        | Tons.     | Tons.     |
| Pennsylvania . . .     | 885,652   | 849,556   |
| Illinois . . . . .     | 450,553   | 364,725   |
| Other States . . . . . | 122,538   | 25,112    |
| Totals . . . . .       | 1,458,743 | 1,239,393 |

The production of Bessemer steel rails by the Bessemer steel manufacturers in 1890 was 1,797,489 tons. The production of 1892, while much larger than that of 1891, was 338,746 tons less than that of 1890.\*

**Production of Iron Ore.**—Mr. J. Birkinbine † states that the output of iron ore in the United States has been as follows :—

| Locality.                          | 1872.   | 1885.     | 1891.     |
|------------------------------------|---------|-----------|-----------|
|                                    | Tons.   | Tons.     | Tons.     |
| Marquette Range . . . . .          | 948,553 | 1,430,862 | 2,482     |
| Menominee Range . . . . .          | ...     | 690,435   | 1,856,124 |
| Gogebic Range . . . . .            | ...     | 119,590   | 2,041,754 |
| Vermilion Range . . . . .          | ...     | 227,075   | 945,105   |
| New Jersey . . . . .               | 600,000 | 330,000   | 525,612   |
| Cornwall, Pennsylvania . . . . .   | 193,317 | 508,864   | 663,746   |
| Lake Champlain, New York . . . . . | 350,000 | 420,000   | 554,865   |
| Missouri . . . . .                 | ...     | 169,162   | 106,749   |
| Ohio . . . . .                     | ...     | ...       | 104,487   |
| Alabama . . . . .                  | ...     | 505,000   | 1,986,830 |
| Imports of ore . . . . .           | 27,000  | 390,786   | 912,864   |

The total quantity of iron ore raised in the United States in 1891 was 14,591,178 tons. The percentages of the different kinds of iron ore

\* *Iron Age*, vol. li. p. 800.

† "Mineral Resources of the United States," 1891, with diagrammatic curves; *Iron Age*, vol. l. p. 780.



contained in the total output has been as follows in the years mentioned :—

| Description.             | 1880.     | 1889.     | 1890.     | 1891.     |
|--------------------------|-----------|-----------|-----------|-----------|
|                          | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| Red hæmatite . . . . .   | 31·51     | 62·38     | 65·65     | 63·92     |
| Brown hæmatite . . . . . | 26·95     | 17·38     | 15·96     | 18·90     |
| Magnetite . . . . .      | 29·97     | 17·26     | 16·03     | 15·88     |
| Carbonate . . . . .      | 11·57     | 2·98      | 2·36      | 1·30      |

**Imports and Exports.**—The report of the United States Bureau of Statistics for the year 1892 has recently been issued.\* The imports of iron and steel into the United States in the calendar years 1891 and 1892 are stated to have been as follows :—

| Description.                                                | 1892.   | 1891.   |
|-------------------------------------------------------------|---------|---------|
|                                                             | Tons.   | Tons.   |
| Iron ore . . . . .                                          | 806,585 | 912,856 |
| Pig iron . . . . .                                          | 70,125  | 67,179  |
| Scrap iron and steel . . . . .                              | 29,228  | 44,434  |
| Bar iron . . . . .                                          | 19,282  | 18,099  |
| Bars, railway, of iron or steel . . . . .                   | 347     | 253     |
| Hoops or band iron . . . . .                                | 1,011   | 186     |
| Hoop, band, or scroll iron or steel . . . . .               | 725     | 685     |
| Ingots, blooms, slabs, billets, and bars of steel . . . . . | 30,586  | 34,685  |
| Sheet plate and taggers, iron or steel . . . . .            | 26,959  | 11,882  |
| Tin plates, terne plates, and taggers, tin . . . . .        | 268,223 | 327,899 |
| Wire rods of iron or steel . . . . .                        | 42,423  | 46,938  |
| Wire and wire rope . . . . .                                | 3,831   | 4,398   |
| Anvils . . . . .                                            | 748     | 813     |
| Chains . . . . .                                            | 544     | 448     |

The exports during the same periods were as follows :—

| Description.                                                    | 1892.  | 1891.  |
|-----------------------------------------------------------------|--------|--------|
|                                                                 | Tons.  | Tons.  |
| Pig iron . . . . .                                              | 15,427 | 14,946 |
| Band, hoop, and scroll iron . . . . .                           | 36     | 162    |
| Bar iron . . . . .                                              | 963    | 1,340  |
| Ingots, bars, and rods of steel . . . . .                       | 205    | 538    |
| Nails and spikes :—                                             |        |        |
| Cut . . . . .                                                   | 6,816  | 4,635  |
| Wire, wrought, horseshoe, and others, including tacks . . . . . | 954    | 847    |
| Plates and sheets :—                                            |        |        |
| Of iron . . . . .                                               | 259    | 344    |
| Of steel . . . . .                                              | 202    | 104    |
| Railroad bars or rails :—                                       |        |        |
| Of iron . . . . .                                               | 486    | 160    |
| Of steel . . . . .                                              | 7,496  | 11,079 |

\* *Iron Age*, vol. li. p. 317.

**Condition of the Blast-Furnaces.**—The blast-furnaces in blast in the United States at January 1, 1893, were as follows :—

| Fuel Used. |   |   |   |   |   | Number of<br>Furnaces. | Weekly<br>Capacity. |
|------------|---|---|---|---|---|------------------------|---------------------|
| Anthracite | . | . | . | . | . | 70                     | Tons.<br>32,772     |
| Coke       | . | . | . | . | . | 138                    | 131,731             |
| Charcoal   | . | . | . | . | . | 38                     | 8,865               |
| Totals     |   |   |   |   |   | 246                    | 173,368             |

The output of pig iron in the United States during the second half of 1892 was about 4,300,000 tons, or a total of 9,100,000 tons for the whole year. The stocks of pig iron at January 1 were 749,906 tons.\*

**The Iron Industry of the Southern United States.**—Dr. W. M. Sweet† describes the rapid growth made by the iron and steel industry of the Southern States of the American Union during the past decade. He publishes tables showing the present position of the industry and its recent growth.

The Southern blast-furnaces made in 1890 more than 19 per cent. of the total quantity of pig iron made in the United States, but in 1880 this percentage was only 9.

**The Manufacture of Tin Plate.**—The output of tin and terne plates in the United States during the fiscal year ending September 30, 1892, is stated by Mr. Ira Aejer‡ to have amounted to 13,646,719 lbs., of which no less than 10,952,725 lbs. was made within the period July 1, 1892, to September 30 of the same year. On September 30 there were thirty-two active works, besides others in course of construction or enlargement, belonging in all to forty-six manufacturing concerns. The wages paid in the United States are stated to compare as follows with those paid in the United Kingdom :—

\* *Iron Age*, vol. li. p. 82.

† *Census Bulletin*, No. 347.

‡ Official Report to the United States Treasury ; *Iron Age*, vol. 1. p. 836.

| Workmen.                | United Kingdom.<br>(Per Box.)   | United States.<br>(Per Box.)  |
|-------------------------|---------------------------------|-------------------------------|
|                         | Cents.                          | Cents.                        |
| Roller . . . . .        | 7                               | 22                            |
| Heater . . . . .        | 5 <sup>1</sup> / <sub>6</sub>   | 14                            |
| Behinder . . . . .      | 3 <sup>1</sup> / <sub>2</sub>   | 7                             |
| Doubler . . . . .       | 5 <sup>3</sup> / <sub>8</sub>   | 15                            |
| Shearman . . . . .      | 2 <sup>1</sup> / <sub>2</sub>   | 9                             |
| Two openers . . . . .   | *48                             | ...                           |
| Scrap boy . . . . .     | †36                             | †75                           |
| Picklers . . . . .      | 2 <sup>1</sup> / <sub>2</sub>   | 5                             |
| Cold rolling . . . . .  | 1 <sup>1</sup> / <sub>2</sub>   | 3 <sup>1</sup> / <sub>2</sub> |
| Annealing . . . . .     | 2 <sup>1</sup> / <sub>6</sub>   | 4 <sup>1</sup> / <sub>2</sub> |
| Tinman . . . . .        | 6                               | 12                            |
| Washman . . . . .       | 6                               | 12                            |
| Riser . . . . .         | 2                               | 4                             |
| Catcher . . . . .       | 1 <sup>1</sup> / <sub>2</sub>   | 2 <sup>1</sup> / <sub>2</sub> |
| Three rubbers . . . . . | } 1 <sup>1</sup> / <sub>2</sub> | 2 <sup>1</sup> / <sub>2</sub> |
| Three dusters . . . . . |                                 |                               |

It will be seen that the average of wages paid in the rolling-mill work in the United States is from two to three times as great as in the United Kingdom, and in the finishing or tinning department about twice as great.

**The Connellsville Coke Region.**—The output of coke in the coke district of the Connellsville region in 1892 exceeded that of any previous year, with the exception of 1890. The quantity of coke made amounted to 6,167,348 tons, valued at 11,179,961 dollars. At the close of the year the ovens at work numbered 13,246.†

**Lake Superior Iron Ore.**—The total quantity of iron ore shipped from the various districts of the Lake Superior Region in 1892 was as follows :—

| Range.              | Tons.     |
|---------------------|-----------|
| Gogebic . . . . .   | 2,973,993 |
| Marquette . . . . . | 2,666,856 |
| Menominee . . . . . | 2,261,499 |
| Vermilion . . . . . | 1,167,650 |
| Mesabi . . . . .    | 4,245     |
| Total . . . . .     | 9,074,243 |

During the preceding year the shipments amounted to 9,003,701 tons.§

\* In the United States shear-men pay openers.  
† Per day.  
‡ *Iron Age*, vol. li. p. 62.  
§ *Ibid.*, vol. li. p. 133.

**The Consumption of Iron on a Railway.**—Details are published\* showing the consumption of metal on the line of the Illinois Central Railway. The maximum yearly consumption of rails since 1887 was in the year 1889–90, when, with 2875 miles of track laid, the consumption of rails amounted to 23,999 tons. In the following year, with the same length of line, the rails laid weighed 14,190 tons; and in 1891–92 the consumption amounted to 15,881 tons, the length of the line being then 2888 miles. The greater portion of the railway is equipped with 60-lb. steel rails, though heavier rails are gradually being introduced. The coal used by this railway in 1892 was 867,109 tons, and the new wheels and axles used in repairs were respectively 12,489 and 2490.

**Cost of Making Pig Iron in Virginia.**—The cost of making pig iron at the Rockbridge Furnace, Virginia, is stated to be as follows:—

|                               | Dollars.    |
|-------------------------------|-------------|
| Coke . . . . .                | 3·78        |
| Ore . . . . .                 | 2·53        |
| Limestone . . . . .           | 0·50        |
| Salaries and labour . . . . . | 1·35        |
| Incidental expenses . . . . . | 0·60        |
| <b>Total . . . . .</b>        | <b>8·76</b> |

This plant was erected in 1884, and was at first a failure.†

**Iron Industry of the Schuylkill Valley.**—In his presidential address at the Schuylkill Valley meeting of the American Institute of Mining Engineers, Mr. J. Birkinbine ‡ traced the early history of the mining and metallurgical industries of Pennsylvania. The earliest written record of the manufacture of iron in that State is the following verse from a poem published in 1692:—

“ A certain place here is, where some begun  
To try some Mettle, and have made it run;  
Wherein was Iron absolutely found,  
And once was known about some Forty Pound.”

In 1731 pig iron is reported to have been sold in large quantities at the Coalbrookdale Furnace, Pennsylvania, at £5, 10s. per ton, local cur-

\* *Iron Age*, vol. i. p. 922.

† *Ibid.*, vol. li. p. 375.

‡ *Transactions of the American Institute of Mining Engineers*, Schuylkill Valley Meeting (advance proof).



| Country.                 | Year. | Production in Tons. |
|--------------------------|-------|---------------------|
| United Kingdom . . . . . | 1892  | 6,709,255           |
| Austria . . . . .        | 1891  | 617,145             |
| Hungary . . . . .        | 1890  | 285,102             |
| Belgium . . . . .        | 1892  | 768,321             |
| Canada . . . . .         | 1891  | 21,331              |
| France . . . . .         | 1892  | 2,022,989           |
| Germany . . . . .        | 1892  | 4,793,003           |
| Italy . . . . .          | 1891  | 11,930              |
| Japan . . . . .          | 1890  | 16,176              |
| Russia . . . . .         | 1891  | 936,000             |
| Spain . . . . .          | 1892  | 211,436             |
| Sweden . . . . .         | 1891  | 490,913             |
| United States . . . . .  | 1892  | 9,157,000           |

**The World's Iron Trade.**—Dr. H. Wedding \* compares the progress of the iron trade in the chief iron-producing countries during the past twenty years. The production of iron ore he tabulates as follows:—

| Country.                | 1870.        | 1880.        | 1890.        |
|-------------------------|--------------|--------------|--------------|
|                         | Metric Tons. | Metric Tons. | Metric Tons. |
| North America . . . . . | 3,081,000    | 7,234,000    | 16,293,000   |
| Great Britain . . . . . | 16,596,000   | 18,314,000   | 14,001,000   |
| Germany . . . . .       | 4,970,000    | 7,238,000    | 11,406,000   |
| Spain . . . . .         | ...          | 3,503,000    | 5,789,000    |
| France . . . . .        | ...          | 2,874,000    | 2,579,000    |

Thus, while the production of Great Britain was in 1890 only 84 per cent. of what it was in 1870, or rather in 1871, that of the United States was more than five times, and that of Germany more than twice as large as it was in 1870. Spain and France, too, show large increases in the last decennium. In the year 1891 both the United States and Great Britain, and Germany also, showed a diminished output of ore.

The imports of iron ore by the different countries are referred to, the author showing that the percentage borne by the tonnage of imported ores to that of the ores raised at home was as follows in the countries mentioned :—

|                          |           |
|--------------------------|-----------|
|                          | Per Cent. |
| United States . . . . .  | 7·8       |
| Germany . . . . .        | 13·3      |
| United Kingdom . . . . . | 32·5      |
| France . . . . .         | 62·4      |

Both the United States, Germany, and Spain export more ore than they import, but the imports of ore into France and the United Kingdom

\* *Stahl und Eisen*, vol. xiii. pp. 230–236.



| Country.                                     | 1892.     |                              | 1891.     |                              |
|----------------------------------------------|-----------|------------------------------|-----------|------------------------------|
|                                              | Total.    | With under 0·17 per Cent. C. | Total.    | With under 0·17 per Cent. C. |
| United Kingdom . . . . .                     | 406,839   | 317,583                      | 436,261   | 350,818                      |
| Germany and Luxemburg . . . . .              | 2,013,484 | 1,616,783                    | 1,779,779 | 1,314,781                    |
| Austria and Hungary . . . . .                | 288,122   | 212,408                      | 221,212   | 95,907                       |
| France . . . . .                             | 287,528   | 196,190                      | 255,401   | 173,880                      |
| Belgium, Russia, and United States . . . . . | 206,667   | 129,028                      | 187,882   | 111,172                      |
| Totals . . . . .                             | 3,202,640 | 2,471,992                    | 2,880,535 | 2,046,556                    |

**The Duration of the Coal Supply.**—R. Nasse \* estimates the supplies of coal still available to be as follows in the countries named, the average annual output for the three years 1889, 1890, and 1891 being also shown :—

| Country.                  | Available Coal.           | Annual Output.           |
|---------------------------|---------------------------|--------------------------|
|                           | Billiards of Metric Tons. | Millions of Metric Tons. |
| United Kingdom . . . . .  | 198                       | 184·2                    |
| Germany . . . . .         | 112                       | 81·8                     |
| France . . . . .          | 18                        | 25·3                     |
| Austria-Hungary . . . . . | 17                        | 20·5                     |
| Belgium . . . . .         | 15                        | 20·0                     |
| United States . . . . .   | 184                       | ...                      |

The author estimates that if the population of the United States increases as it has of late, then within a hundred years the density of population may be as great as that of Germany, in which case the annual output of coal would be about 1134 millions of tons. That being so, the coal supply even of the United States would not last more than about 650 years. As to Europe, the author estimates that the first failure in the supply of coal will take place in France, Austria, and Belgium, in, at the latest, 500 years time, then in the United Kingdom, and finally in Germany. In this latter country the supply of coal may last for 800 or 1000 years. The coal supply of Central Europe may possibly be at an end in about 670 years from 1890.

Mr. M. Stirrup † discusses the question of the world's supply of coal, and points out the influence of the coalfields of India, China, and Japan on the duration of the supply. Substitutes for coal are also discussed, and their distribution.

\* *Stahl und Eisen*, vol. xiii. p. 306.

† *Transactions of the Manchester Geological Society*, vol. xxii. pp. 227-234.





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